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Canadian Institute of Mining and Metallurgy

THE TRANSACTIONS

OF THE

Canadian Mining Institute

(With which is incorporated the Transactions of the Mining Society of Nova Scotia)

1919

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VOLUME XXII

"The Institute as a body shall not be responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at its meetings."—*By-Laws, Sec. 49.*

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ERRATA

PAGE 184—Vertical projection should be turned end for end.

PAGE 200—Discussions by Messrs. O. Hall and F. W. Gray should be on page 195.

PAGE 336—Line 12 from top: Gold 6,600 .10%, should read Gold 6,600 0.1 oz.

Line 16 from top: Gold 12,000 .10%, should read Gold 12,000 0.1 oz.

PAGE 337—Line 2 from top: 0.10 per cent gold should read 0.1 oz. gold.

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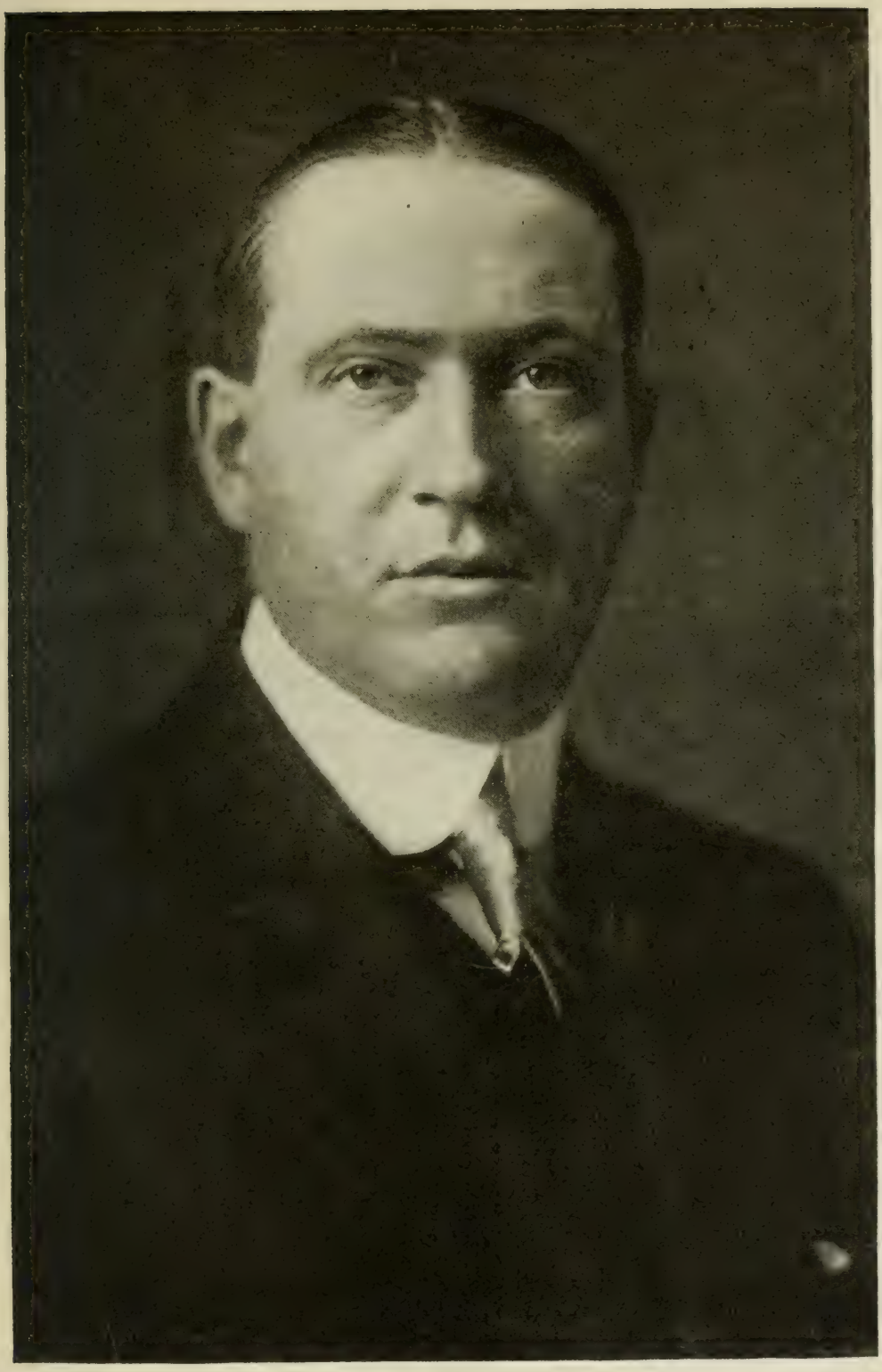

Mr. D. H. McDougall,
President of the Canadian Mining Institute,
1919–1920

REPORT OF THE COUNCIL FOR THE YEAR ENDING DECEMBER 31, 1918

In presenting its report on the activities of the Institute for the past year, the Council considers it seemly to express the profound relief and thankfulness that all must feel at the successful termination of the Great War. The universal rejoicing this has occasioned is the more pronounced by reason of the anxiety experienced earlier in the year during the critical time of the German offensive in March and April. On November 11th, 1918—a date that will be indelibly engraved on the pages of history—the stupendous struggle was brought to a close by the admission by Germany of defeat. The cause of righteousness and justice, of human liberty and freedom, thus triumphed, as none ever doubted was destined, however long deferred. Our elation at this glorious consummation is tempered only by our regret that those who laid down their lives to attain it cannot share in our satisfaction, or receive the meed of tribute and gratitude that their devotion and sacrifice to duty deserves. During the course of the war twenty-one members of the Institute were killed in action or died from wounds. Happily this is a relatively small proportion of the total number of members (in all one hundred and sixty-eight), who were on overseas' military service, and of whom the majority volunteered at the first outbreak of hostilities. The distinguished nature of their services has been attested by the promotions and the decorations they have won, and by the frequent mention of the names of members of the Institute in despatches from the Commander-in-Chief of the British Forces. One member received the honour of knighthood, and holds the rank of Major-General; another who left Canada in command of a Highland battalion, is also now a Major-General; a third holding a captaincy at the beginning of the war within two years rose to be a Brigadier-General; the promotions to colonelcies have been numerous, and at least fifty per cent of those members who enlisted as privates have gained commissions as officers. The Canadian Tunnelling Companies were officered almost exclusively by

members of the Institute, and the efficiency of these units was notably distinguished, and especially so in connection with the great operation at Messines Ridge. The Institute may well be proud of the Overseas' record of its members. From the commencement of the war the Institute has kept in close touch with the members on military service.

The war work of the Institute itself in co-operating with the Department of Militia and other Departments of the Government has been detailed in preceding Reports of the Council. This work has been continued to some extent during the past year. Recently, the services of the Institute have been utilized by the Department of Labour in assisting with demobilization plans and in finding employment in productive industry for labour released from munition works.

CANADIAN DEPARTMENT OF MINES

In February last, a deputation appointed by the Council waited on the Prime Minister to urge that, having regard to the great importance of increasing sources of revenue to relieve the financial burdens imposed by the war on the Dominion, Government take immediate measures to stimulate, so far as possible, the discovery and effective exploitation of Canadian mineral resources, since of all Canadian industries, that of mining possesses the greatest possibilities for profitable expansion, and is, moreover, the basis of innumerable subsidiary industries. It was pointed out that this purpose might best be accomplished by strengthening the Department of Mines and by enlarging its range and influence. Duplication of effort and the dissipation of funds and energy consequent on the appointment of Commissions to undertake duties that properly were within the scope of the Department were deprecated, and the unification of such efforts advocated. The desirability of providing that the control of the Canadian metal trade should be, as far as practicable, in our own hands, was represented; and the advantage indicated of co-operation between Canada and other parts of the Empire to insure that the mutual requirements of the Empire, for both war and peace, be met from the joint resources. To facilitate

efforts in these directions the opinion was expressed that the Department of Mines should concern itself more directly with promoting commercial interests in connection with mining; and should be in a position to correlate the information it has accumulated in respect of resources with information relating to trade. In short, it was urged that all matters pertaining to the welfare, development, and progress of mining, should be made the business of the Department, and in order that it might perform this function effectively, the recommendation was made that the two branches of the Department, as at present constituted, be united. Special consideration of the problem of inducing exploration for minerals was requested; and, as an essential provision for the encouragement of prospecting on Crown lands under Federal control, the early passage of a mining law to replace the existing regulations governing title to mineral lands was strongly counselled. It may be noted that following the presentation of the memorial the Institute was invited by the Government to nominate a representative to serve on an important Committee of the Department of Mines, to report on matters having to do with the control of the metal trade in Canada.

MINING TAXATION IN BRITISH COLUMBIA

In 1917, the Legislature of British Columbia enacted a measure entitled "An Act to Amend the Taxation Act." This legislation imposed a most onerous burden on the mining industry of the Province; was unjust in principle, and possessed certain very objectionable features, including a retro-active clause. The passage of this Bill was officially protested by the Western Branch of the Institute; and subsequently its repeal was urged by the Council. An amending measure was introduced by the Provincial Government in 1918, by which some of the more glaringly inequitable provisions of the 1917 Act were modified; but unless the existing law is repealed and replaced by a measure based on right principles as regards the basis of mine taxation, there can be no doubt but that the progress of the mining industry in British Columbia will be

impeded and that it will be more difficult than formerly to interest capital in the development of mines in that Province.

The Stimulation of Gold Production

The difficulty of profitably maintaining gold production in the face of the steady and continuous advance of the cost of supplies and of labour, without the equalizing factor, as in the case of other metals, of an appreciation in the marketable value of the commodity produced, became more acute during the year, and in Canada several mines in which the tenor of the ore was of only moderate grade were compelled to close. Having been given to understand that it was regarded as highly important in the national interests and for the successful prosecution of the war that the production of gold should be maintained at a maximum, the Sub-Committee of the Council on 'Gold' communicated with the Hon. the Minister of Finance to ascertain whether the Canadian Government proposed to take any steps to assist gold mining in this country. No definite reply was received, but it was intimated that the initiative rested with the Imperial authorities. Shortly thereafter information was received that a Committee, representing the interests of gold mining throughout the Empire, had been formed in London to lay their case before the Imperial Government with a view to securing assistance for the industry. The Institute's Committee thereupon intimated its readiness to co-operate with the Committee in London, and the offer being accepted, Dr. Willet G. Miller, who was in London at the time on official business, was nominated, and consented to act, as the representative of the Canadian industry on this Committee, whose appeal subsequently to the British Treasury resulted in the appointment of a Commission to survey the situation and make recommendations respecting what measures might be adopted to ameliorate conditions.

Educational Reform

At the twentieth Annual General Meeting of the Institute a resolution was adopted endorsing the views advanced by Mr. C. V. Corless to the effect that any final eradication of the

existing antagonisms and misunderstanding between capital and labour must be based on an efficient socializing education of both parties to the dispute; and that this could only be accomplished by reforming our educational system to conform with this conception, and make school training a preparation for democratic social relationships, whether in industry or for what is more generally understood by the expression 'good citizenship.' It was further resolved that the Institute should seek the co-operation of other technical and industrial bodies of national standing, so that joint action might be taken in representing to the educational authorities of the Dominion the need and urgency of effecting reforms on the lines advocated. The following associations were accordingly communicated with and signified their readiness to co-operate: The Engineering Institute of Canada, the Society of Chemical Industry (Canadian Section), the Canadian Pulp and Paper Association, the Canadian Textile Institute, the Canadian Fisheries Association, the Canadian Manufacturers Association, the Trade and Labour Council, and the Royal Canadian Institute. A meeting of the representatives of these organizations was held in Ottawa in October, to consider how the matter might most effectively and impressively be brought to the attention of the authorities. The outcome of this meeting was the appointment of a Committee, under the chairmanship of Dr. W. L. Goodwin, to formulate a definite programme looking to the introduction of ethical instruction (education for citizenship) in the schools. It was further decided that the presentation of the Committee's proposals to the educational authorities in the respective Provinces should be delegated to the branches or sections of the different societies interested and working in concert. The tentative recommendations of the Committee, are as follows:—

1. That teachers be especially trained to appreciate the industrial need for intelligent and responsible people both in the shop and the office, and to adopt the school-room to the interests of the community. Better salaries for teachers will then be necessary and deserved.

2. That attendance at school be made really compulsory over a wider age period; full time until 14 years of age and in some form of extension school or night or correspondence classes for a time thereafter.

3. That an effort be made to arouse in the pupil an interest in Canadian industries, especially in those of his community, and that this interest be so guided as to avoid industrial misfits. A local committee should be chosen to arrange for short talks on industrial topics, visits to offices, factories, mines, gardens, farms, orchards, etc., and for demonstrations of manufacturing processes. Such a committee could assist teachers and parents as vocational advisors. There should be provided pamphlets and exhibits to make available to everybody, through the public libraries and schools, information on Canada's resources and industries.

4. That every school be provided with facilities for some mutual training and domestic science, as a part of the course of each student.

5. That there be regular readings and talks explaining the meaning, opportunities and obligations of citizenship. The need of doing honest conscientious work should be emphasized, such as is done through the 'Boy Scouts.'

6. That co-operation in the matter of text books be sought by the various provinces.

7. That larger school units usually make for greater efficiency and economy of instruction.

Co-operation with the Engineering Institute of Canada

As an evidence of the good-will existing between the Engineering Institute of Canada and the Canadian Mining Institute, it may be noted that in April last the Council of the former adopted a resolution favouring co-operation between the two institutions in all matters of common interest, and to give effect to this desire appointed a Committee to represent the Engineering Institute on such occasions as it might appear opportune to

confer with a view to arranging for co-operative action in any particular direction. This friendly intimation was appreciatively received and reciprocal action was taken by the appointment of a Committee to represent the Canadian Mining Institute in a similar manner. The fraternal relations existing between the two institutions have been undoubtedly strengthened by this arrangement. During the year the two societies co-operated successfully in opposing an attempt on the part of a group of men, in no sense representative of the engineering profession, to secure powers under a Bill of incorporation for the control of engineering practice in the Province of British Columbia. The proposals, also, of the Saskatchewan Branch of the Engineering Institute of Canada to introduce legislation for the regulation of engineering practice in Saskatchewan were referred to a joint Committee of the two Institutes, at whose meeting on December 2nd the following resolution was adopted:

" That in the opinion of this meeting, the question of legislation is of so great importance to Engineers of all branches of the profession, that it should receive very careful consideration and should have the approval of the majority of Canadian engineers before being enacted as, otherwise it may jeopardise the future of effective legislation and defeat the objects in view The members of the Mining Institute will therefore recommend to their Council, that legislation be opposed until it has had more mature consideration, but that the Mining Institute join hands with the Engineering Institute of Canada, in endeavouring to frame an acceptable Act."

AFFILIATION OF THE MINING SOCIETY OF NOVA SCOTIA WITH THE INSTITUTE

It is most gratifying to the Council to be able to report the successful consummation of the arrangements for the affiliation of the Mining Society of Nova Scotia with the Canadian Mining Institute. Negotiations to this end were first entered into some twelve years ago, but no basis of understanding was reached until 1914, when a delegation comprising the President for that year, Mr. G. G. S. Lindsey, and other members of the Council of the Institute attended the Annual Meeting of the Mining Society of Nova Scotia and after a conference with the Executive of that body, submitted the terms on which the union as now effected is based. During the two years

following the declaration of war the Annual Meetings of the Mining Society of Nova Scotia were not held in the customary manner, and in consequence consideration of the Institute's proposals were deferred until 1917, when the Society appointed a Committee to report thereon. At the Society's Annual Meeting in May, 1918, the Committee reported in favour of union, and by resolution was empowered to conclude arrangements for affiliation with the Canadian Mining Institute "on a basis not less favourable to the Society than the proposals of the Institute under date of the 15th of April, 1914, with the following modification, namely, that the Institute will agree to contribute to the Treasury of the Society annually a sum not less than two hundred and fifty dollars." By vote of Council this modification has been agreed to. It is believed that the results of this consolidation will prove to be in the highest degree mutually beneficial.

IRON AND STEEL SECTION

The establishment of an Iron and Steel Section of the Institute was formally decided upon at the Annual General Meeting. The organization of the work of the Section has, however, been seriously delayed by a series of untoward circumstances, not the least of which was the outbreak of the epidemic of influenza in the late autumn, necessitating the cancellation of the arrangements that had been made for meetings during the winter. It is hoped, however, that the Section will be placed on a thoroughly effective and business-like basis during 1919.

MEETINGS

The Annual General Meeting of the Institute was held in Montreal, on March 6th, 7th and 8th. The attendance was in the neighbourhood of a hundred and fifty. The gathering was a more than usually representative one, by reason mainly of the fact that meetings of the Advisory Committee of the Munition Resources Commission and of the Advisory Committee on Mining and Metallurgy of the Research Council

were convened for the same dates as those of the Annual Meeting of the Institute. The personnel of the Committees referred to consisted of members of the Institute from each of the Provinces in which mining is carried on; and they represented also every branch of the mining and metallurgical industries of the Dominion. Their presence at the meeting, therefore, contributed materially to its success. The Institute's guests of honour at the annual dinner were the Hon. Martin Burrell, Minister of Mines, Mr. H. H. Vaughan, President of the Engineering Institute of Canada, and Mr. Bradley Stoughton, Secretary of the American Institute of Mining Engineers.

Other successful meetings have been held during the year in Montreal, Toronto, Winnipeg, Calgary, Edmonton, and Vancouver under the auspices of the respective Branches.

BRANCHES

Two new branches have been established during the year, namely the Manitoba Branch, with headquarters at Winnipeg; and the Northern Alberta Branch, with headquarters at Edmonton.

PUBLICATIONS.

The publications of the Institute during 1918 comprised twelve numbers of the MONTHLY BULLETIN, and Vol. XXI. of the TRANSACTIONS. The latter, it is expected will be ready for distribution early in February next. The Secretary desires gratefully to acknowledge the assistance rendered him in the editing of manuscripts by Mr. John E. Hardman, and other members of the Publication Committee. Sincere thanks are also due to those members who contributed articles or who acted as special contributors to the BULLETIN, and especially to Mr. J. C. Murray and Mr. R. P. D. Graham. Acknowledgements are also due to the *Engineering and Mining Journal* for its kindness in contributing regularly a monthly review of the metal markets; and to the American Institute of Mining Engineers which has most generously afforded the Institute the

privilege of simultaneous publication of its monthly index of mining and metallurgical literature.

Library

No purchases of books, with the exception of a few annual works of reference, have been made during the year.

A Branch library has been established by the Northern Alberta Branch at Edmonton, to which a set of the Transactions has been presented by the Council. Sets of the Transactions have also been donated to the Mining Society of Nova Scotia, the Vancouver Chamber of Mines, and the Haileybury School of Mines.

Members on Military Service.

At the time of the signing of the armistice there were 107 members on military service overseas, of these eightteen joined the Allied Forces since January 1st, 1918, as follows:

B. S. Ashley, A. E. Cameron, N. O. Carpenter, J. M. Cohen (U.S. Army), W. S. Cupples, A. I. Davis, J. H. Disney, J. C. Finnan (U. S. Army,), Albert E. Hall (U. S. Army), B. A. McCrodan, W. St. J. Miller, C. E. Nighman (U. S. Army), C. O. Noble (U.S. Army), F. S. Norcross (U.S. Army), R. E. Rickard, H. S. Robinson (U.S. Army), W. L. Stevenson (U.S. Navy), E. E. Watts.

Mr. John R. Cox enlisted March, 1917, but this was not reported to the Institute, and his name was therefore, not included in last year's list of members serving with the colours.

Membership

The very considerable increase in the membership, from 1,118 at the close of 1917 to a total of 1,302 at the close of 1918, is recorded with satisfaction. One-third of this increase is attributable to the affiliation of the Mining Society of Nova Scotia with the Institute, resulting in an accession of approximately ninety members; while accessions to nearly the same extent followed from the successful organization of the Mani-

toba Branch. For their initiative in this latter connection acknowledgments are due, in particular, to Mr. R. C. Wallace, Mr. Thos. B. A. Price, and Mr. F. de Sieyes. The accessions during the year are classified as follows:

Ex-officio Members	3
Members	173
Associate Members	77
Student Members	2
Affiliated Student Members	11
Honorary Members (ex-officio)	1
Corresponding Members	1
	268

The losses by death, resignation and removal were as follows:—

Deaths	26
Resignations	29
Removals	29
	84

The loss by death of the following members is recorded with deep regret:

Major W. F. Battersby (in action), Barclay Bonthrone, S. H. Boright, A. B. Clabon, Dr. Jas. Douglas, H. W. DuBois, Capt. W. G. Foster (in action), T. L. Goldie (in action), J. M. Gordon, Lieut. T. C. Gorman (in action), John F. Hunter, Henry Kehoe, Major W. E. Lawson (in action), Lieut.-Col. J. A. MacDonell, J. W. Mahon, Col. Wm. Hamilton Merritt, Donald McKellar, John McMartin, G. O. Randolph, C. C. Rhodes, Cpl. C. H. Rowlands (in action), E. L. Steindler, Dr. C. R. Van Hise, C. E. Watson, S. W. Werner and Bruce White.

The following members resigned their membership during the year:

Jas. Anderson, G. C. Bateman, Thos. H. Cameron, N. B. Davis, H. Donkin, F. E. Fillion, E. Jacobs, C. W. Jessop, W. McA. Johnson, Robt. Livermore, H. L. Manley, W. T. Mason, G. F. Murphy, D. B. Rochester, A. S. Stevens, and John E. Williams. In addition the subscriptions of thirteen affiliated student members were not renewed.

The following table enables a comparison to be made between the membership returns of 1917 and 1918:—

	Dec. 31, 1917	Dec. 31, 1918
Patrons	5	4
Corresponding Members	15	15
Honorary Members	6	7
Ex-Officio Members	48	50
Life Members	10	12
Members	894	1,014
Associate Members	122	182
Student Members	5	7
Affiliated Student Members	13	11
	1,118	1,302

D. B. Dowling,
President.

H. Mortimer-Lamb,
Secretary.

Treasurer's Report

During the four years of the war the Institute has exempted members on military service from the payment of fees. Since 1914, the costs of printing and publishing have advanced nearly 100 per cent, and in other directions the expenses of the Institute have been increased largely. It is the more gratifying, therefore, to be able to report that the financial affairs of the Insti-

tute at the close of the year 1918 are in a very satisfactory condition. All liabilities have been readily met from current revenue. The receipts from life membership fees have been invested in Government securities. It may be noted also that receipts from members' annual subscriptions constitute a new high record, being $1,855.00 in excess of last year.

Receipts and disbursements for the year ending December 31st, 1918, were as follows:

RECEIPTS

Cash in Bank 1st January, 1918		$4,990.36
Subscriptions :		
Annual	$8,830.00	
Less: Paid in advance of 1918	100.00	
	$8,730.00	
Life Membership	300.00	
Students	15.00	
Arrears	1,110.00	
Advance	925.00	
		11,080.00
Publications :		
Sales	491.15	
Advertisements	1,826.38	
Binding	268.00	
Index	83.00	
		2,668.53
Miscellaneous :		
Dominion Government Grant	3,000.00	
Bank Interest	173.03	
Revenue from Investments (Life Membership, Fees, etc.)	805.00	
Sale of Buttons	3.00	
		3,981.03
		$22,719.92

DISBURSEMENTS

Publications :			
Printing and Distributing	$4,496.18		
Editor's Salary	1,600.00		
		6,096.18	
Meetings :			
Meetings		289.85	
Secretary's Office :			
Salaries	$4,860.00		
Less: Chargeable to Publications	1,600.00		
		3,260.00	
Rents, Rates and Taxes		$1,030.15	
Telephones and Telegrams		172.13	
Postages		341.82	
Express		23.31	
Printing and Stationery		328.77	
Travelling Expenses		802.72	
Auditors' Fees, Insurance, Removal Expense, Bank Exchange and Miscellaneous Expenses		360.01	
		$12,704.94	
Permanent Fund :			
Furniture		744.55	
Library		148.04	
Victory Bonds		3,003.61	
Reserve to complete Vol. XXI		3,000.00	
Balance in Bank		3,118.78	
			$22,719.92

H. MORTIMER-LAMB,
Treasurer

Audited and verified:

(Signed) P. S. ROSS & SONS,
Chartered Accountants.

Montreal, January 9, 1919.

PRESIDENTIAL ADDRESS

By D. B. Dowling

(Annual Meeting, Montreal, March, 1919)

The present Annual Meeting of the Institute is, for several reasons, a notable one. In the first place, this is our first meeting since the suspension of active hostilities in the Great War. The Institute is justly proud of the part played by its members, and of the record of the mining profession as a whole. We mourn, and honour, the memory of many who will never return. At the same time, we rejoice that we are able to again welcome here many of our members who have returned from the scenes of their brilliant exploits overseas; and we are glad to have the assurance that soon the remainder will be coming home. Our engineers have demonstrated, as we knew they would, their heroism and tenacity on the battlefield, and they have on all occasions compelled admiration for their skill and ability in the construction of military works, and for their great adaptability and initiative in the various operations in which they have taken part. The past few years have afforded unmistakeable evidence, had such been needed, that the fire of patriotism burns as hotly in the breasts of mining engineers and miners as in those of any class. Their wish to participate in the war even more fully than they did was only checked by the absolute need to the nation of their services in providing fuel and other materials requisite for the manufacture of munitions.

The present meeting is also notable in that with it the Institute attains its majority. From small beginnings, it has grown to be thoroughly representative of the mining engineers and the mining skill throughout the whole Dominion. Our doors are opened wide to all those whose study or experience makes them an asset to Canada in solving those problems which are to be met with in the proper utilization of our mineral resources.

This meeting will be notable for still another feature—the inauguration of joint sessions with the American Institute of

Mining and Metallurgical Engineers, at which questions of international interest will be discussed. The joint meeting of the American Institute with the Canadian Mining Institute, held in New York in February, indicated the close bond of sympathy that exists between us, and we are glad in turn to welcome the representatives of the American Institute at this meeting, and with them to rejoice at the successful termination of the War.

We have reached our majority at a momentous period in the history of Canada, and our responsibilities are greater than at any previous time. Canada, as a belligerent in the Great World War, has demonstrated her virility and has amply vindicated her position as a great nation in the British Commonwealth. She has now to show her ability to recuperate under very trying circumstances, and, for the first time, without assistance from outside sources.

As a people we have a debt to pay, and we must realize that it can only be met by industry. The proper utilization of labour, so that it may gain the maximum return for the nation, is necessarily the great problem of the future. The self-evident fact that unskilled labour produces the smallest return needs to be emphasized. National efficiency demands that technical education in all lines shall be promoted to the utmost.

For many of the nations of the old world, the scope of labour is restricted. For some, the production of food and clothing is the main avenue; for others, the possession of fuel has opened the way to great manufacturing industries; while some of the small states depend on the production of various raw materials. The depletion of national assets is greatest when production consists of raw materials alone; it is less where manufacturing is the main industry; and it is least where the products of the soil form the commercial asset.

The depletion of their natural resources, especially in minerals, is one of the serious problems facing the nations of Europe, and it is the cause of much of the insecurity felt by the smaller powers. The large organized powers have cast covetous

eyes on the mineral riches of their weaker neighbours, as witness Germany's plea for "a place in the sun." With the close of the war, the economic struggle to maintain or attain manufacturing supremacy will be renewed, and each nation will attempt to conserve and retain for itself its own raw materials. Such nations as possess raw materials but have no manufacturing facilities will find large outside markets ready to absorb the former, and this opportunity will undoubtedly be offered to Canada.

We, however, are happily situated. The possibilities for the expansion of our agricultural industry are immense, and this industry yields us annually a large income, without a corresponding depletion of our assets. Moreover, in fuel and waterfall, we have almost boundless sources of power for the establishment of manufactories. Our water powers constitute one of our greatest natural assets, and, as in the case of food production, their utilization is not a charge against our resources. Our aim, therefore, should be to develop to the utmost not only our agriculture, but also our manufacturing industries, which in turn will provide us with home markets for our own raw materials. Doubtless, the manufacture of foreign raw materials may be of advantage to us, as it has been, for example, to England. But we must not lose sight of the fact that, as time goes on, the purchase of foreign unmanufactured articles will become increasingly more difficult. Restriction of manufacturing activity must follow unless provision is made for adequate supplies of domestic raw materials.

Our mining interests will never lack foreign markets for their raw products, but it seems desirable that these products should be utilized at home. Many of our resources of the less precious materials have, in the past, been neglected for the want of a home market. Canada has spent vast amounts to keep foreign labour employed, when, by more exploration and by the development of cheap power, the materials could be fabricated at home.

The stability and permanence of our manufacturing industry thus seems to depend, to a large extent, on our knowledge of our natural resources, and on the proper application

of that knowledge. It would seem that the most economical use of our resources would be to offer them in the markets of the world in a manufactured state. If our national development is to be well-balanced, we must lay our plans so as to ensure progress along three main lines: the science of agriculture must be fostered; experts must be trained for locating and husbanding our natural resources; and skilled technicians must be produced whose business it will be to convert these raw materials into manufactures.

The return of the men from overseas, and their release from the army, has created a labour problem, and the attention of governmental and private committees will be devoted to placing this body of men at remunerative work as quickly as possible. This may, for a time, artificially stimulate the manufacturing industry, but if the economic equilibrium is to be maintained, agriculture and mining must also be fostered. The maintenance of supplies of raw materials for our many existing industries, as well as for possible new industries, will be a national obligation. The responsibility in this direction rests very heavily on the members of this Institute; on the explorer and geologist, to examine and report on potential mineral-bearing regions, and to call attention to new minerals and their possible uses in the arts or manufactures; on the prospector, to make discoveries of mineral deposits; and on the mining engineer, to recover economically the mineral riches from such deposits.

We know that the authorities are alive to the needs of the country during this delicate constructive period, but to cope successfully with the situation they need the help of everyone. It is no easy matter to encourage prospecting when the prices of metals and minerals are falling. On the other hand, there is always the possibility that the demands of the chemical industry, or of the metallurgical industry, may, from time to time, stimulate the search for certain minerals and ores. The various Provincial Governments are no doubt considering possible schemes for the encouragement of prospecting, but the burden of a general exploration of the country is, and has long been, on the Federal Government. Very much of the success of the

work already accomplished in this direction must be credited to the Geological Survey. During the war, many members of the staff have been engaged overseas, and the efforts of the rest have been diverted to work more or less directly connected with the supplying of munitions. Now, with the return of more normal conditions, an enlarged programme is being arranged, and its fulfilment will be facilitated by the keen realization by the Minister of Mines of the needs of the mining industry and of the country.

SOME EQUIPMENT FOR A COPPER SMELTER

By E. J. Carlyle.

(Annual Meeting, Montreal, March, 1919)

The equipment described in the following paper is, perhaps, suitable only for a special set of conditions. I hope, however, that there may be some points which will be of general interest.

At the outset I wish to credit Mr. M. R. Hull, now Chief Engineer at the McGill smelter of the Nevada Consolidated Copper Company, with many of the ideas and details described.

BINS.

To indicate the conditions governing the bin design it is necessary to state here that the blast furnaces have four charging doors on each side at 7′ centres, and it was decided to charge the furnaces with a four-compartment scale car, described below, which would charge the whole length of one furnace at once. Accordingly the scale car has four compartments at 7′ centres, and the discharge openings in the bin floors and the columns between these openings are spaced at that interval. Further, to enable charge trains to run on both sides of the furnaces without cross-overs, there are two tracks beneath the coarse ore section of the bin, and two rows of feeders.

A cross-section of the bins is shown in Fig. 1. The double compartment, 29′ 5″ wide inside, is for blast furnace materials, and the single compartment, 19′ 5″ wide inside, is for fine ore and flux for the roasters and reverberatories.

The bins are of flat bottom construction, and as the ore is heavy, are shallow in proportion to their area. They are carried on a substructure of reinforced concrete.

To make the operation of weighing furnace charges as simple as possible the arrangement shown in Fig. 2 was devised. A scale car is placed so that a discharge feeder is over each of the four compartments. The operator without leaving his cab pulls a lever which starts the four feeders working, and stops them as

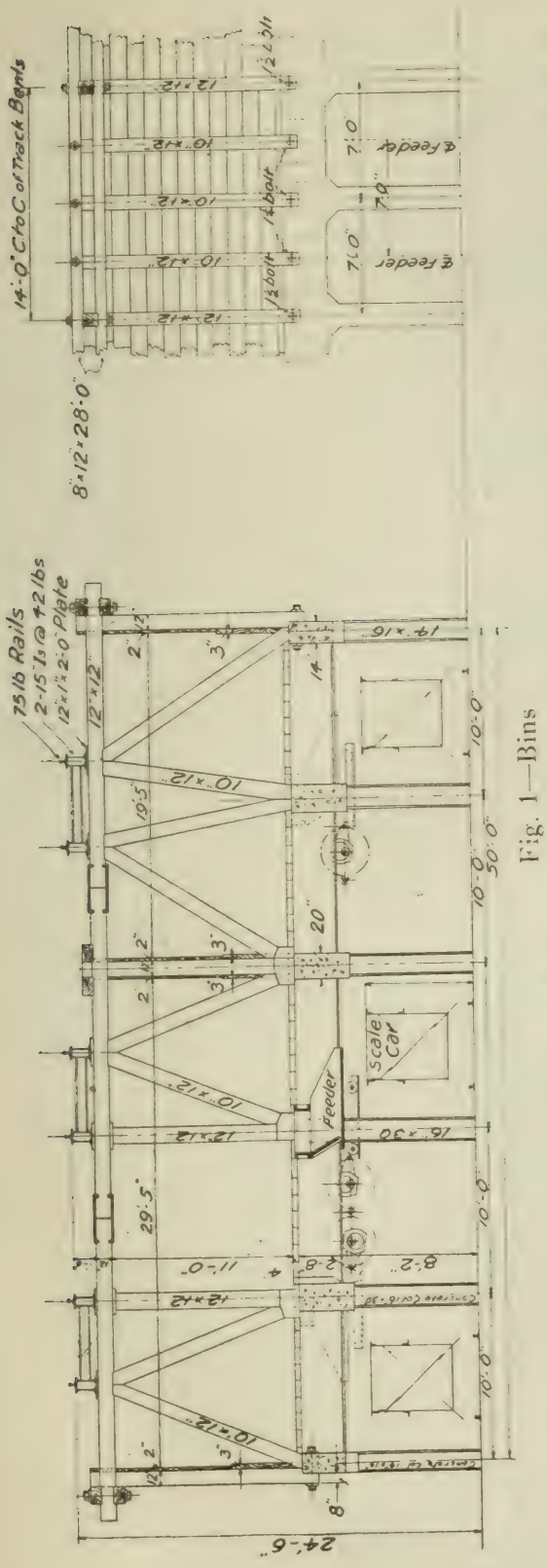

Fig. 1—Bins

soon as the scale beam in his cab shows that the required weight has loaded.

The automatic feeder and driving mechanism is shown in Fig. 3. The feeder is a box or hopper suspended beneath an opening 30″ square in the bin floor. The bottom of the feeder is a removable cast iron plate on a carriage which is moved forward and back by the eccentric and plunger.

The motor driven line shaft S1, extends the full length of the bins and runs continuously, driving the gears G, which are loose on the short shaft S2. When the operator throws in the clutch C, the shaft S2 actuates the four eccentrics driving four feeders (See Fig. 2). The eccentrics are set at 90° so that the four feeders deliver their loads to the scale car in rotation, thus producing less jar on the scales, and enabling the operator to weigh more closely than if all discharged simultaneously.

As soon as the operator releases the lever the clutch C is automatically disengaged by a counterweight.

With this arrangement the feeders will be in operation

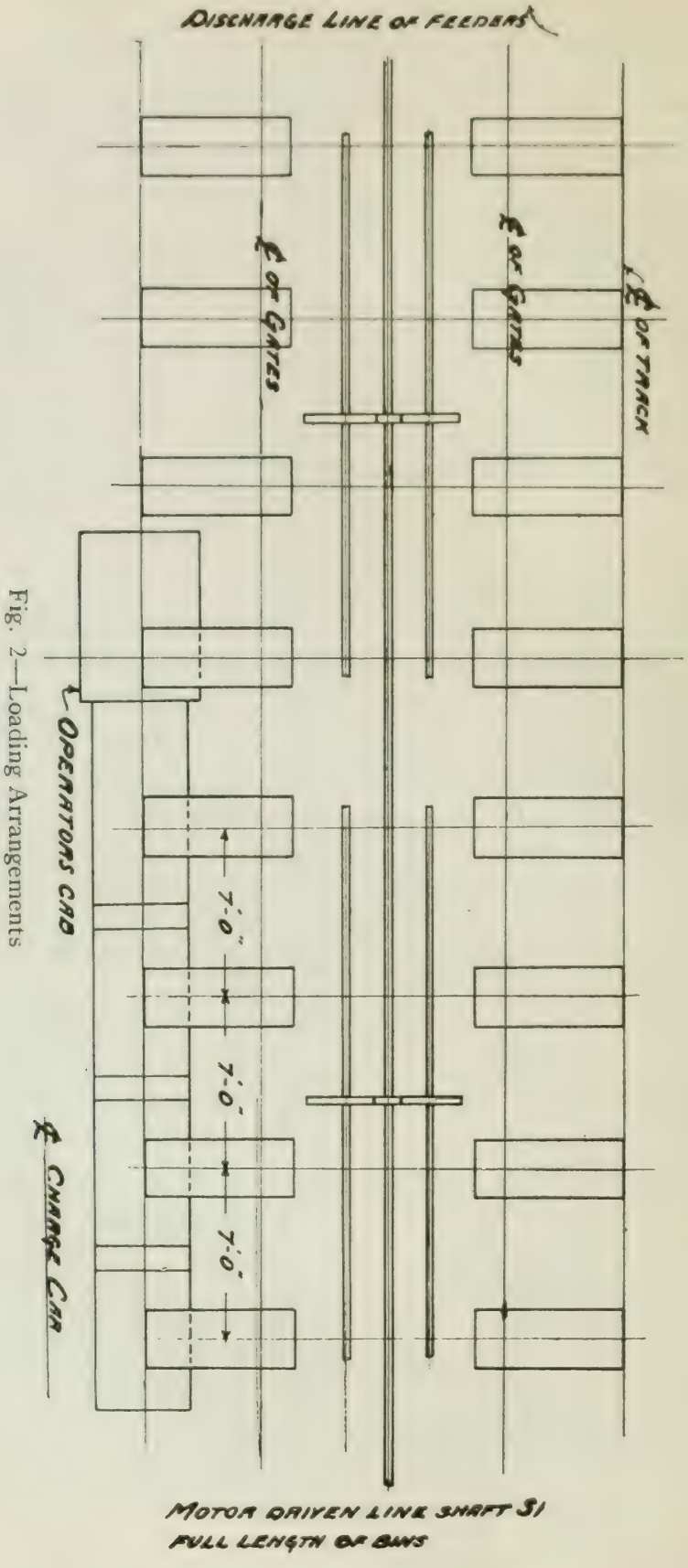

Fig. 2—Loading Arrangements

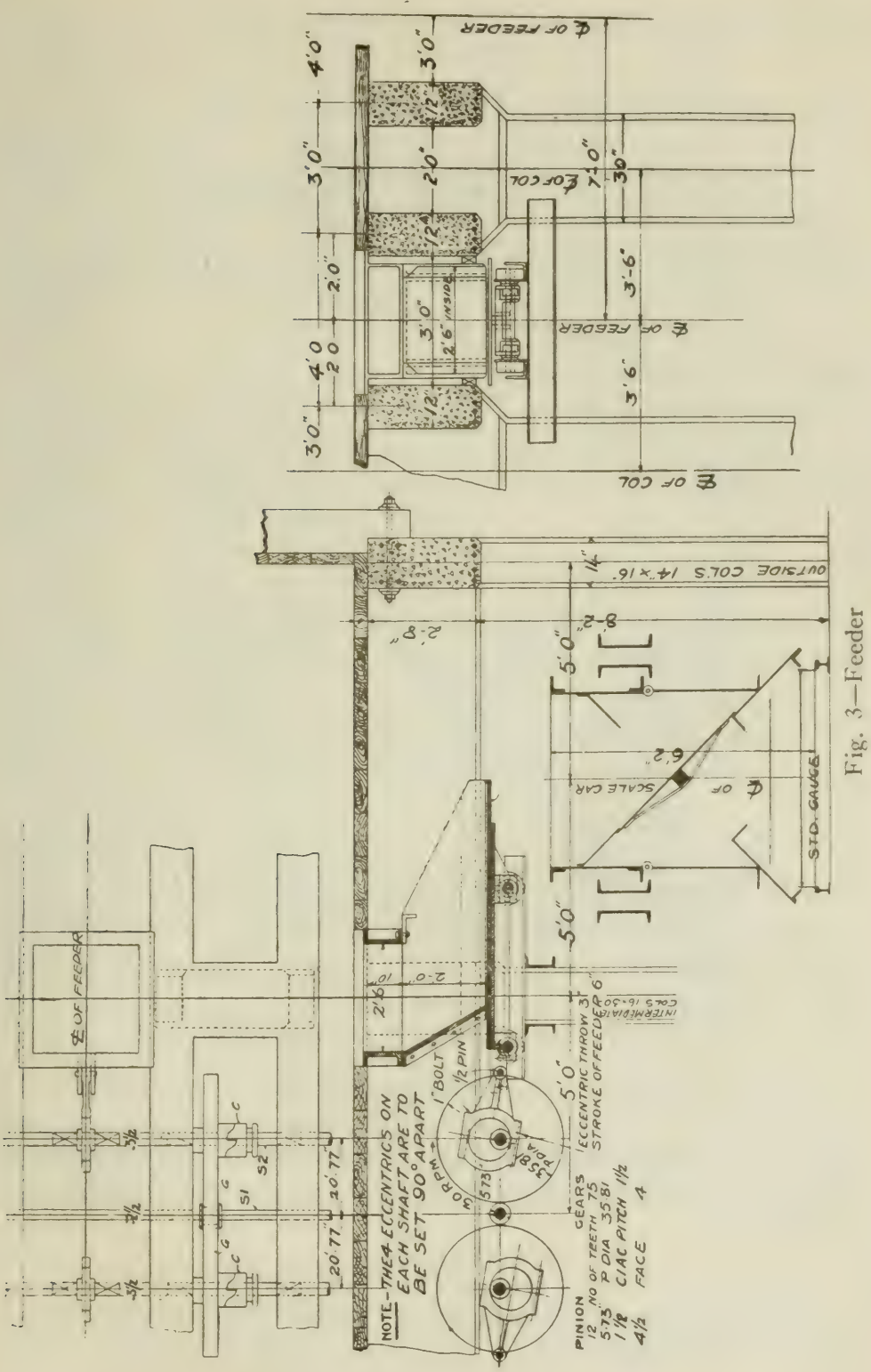
℄ OF FEEDER
℄ OF COL
OUTSIDE COLS 14"x16"
SCALE CAR
STD. GAUGE
℄ OF FEEDER
INTERMEDIATE COLS 16"x30"
NOTE-THE4 ECCENTRICS ON EACH SHAFT ARE TO BE SET 90° APART
1" BOLT
1/2 PIN
PINION
GEARS
1" ECCENTRIC THROW 3" STROKE OF FEEDER
20'77"

Fig. 3—Feeder

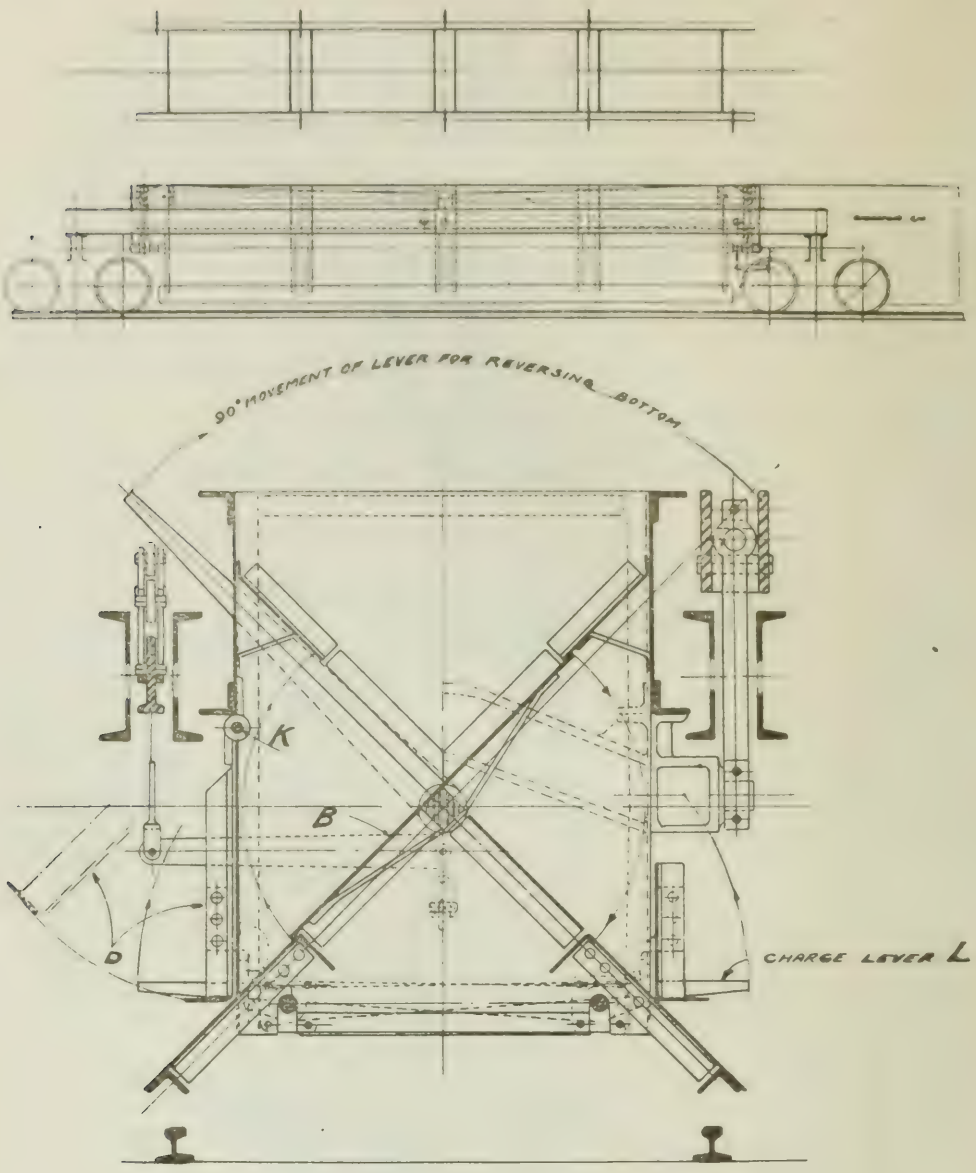

Fig. 4—Charging car.

two minutes to discharge 25 tons of ore into a scale car, and one operator can make up the charges and run the car between bins and furnaces.

SCALE CAR

Fig. 4 will give a general idea of the scale car. It consists of a four-compartment body hung on a system of weighing levers

between two bogie trucks, and an operator's cab containing the scale beams, motors and controllers.

When 'spotted' alongside a blast furnace each compartment will be opposite a charging door. When the charge lever L is raised the side door D, hinged at K, is released and forced open by the weight of the charge, which will then flow into the furnace. There is a separate door and charge lever for each compartment so that any or all compartments can be discharged through any furnace door as required by the condition of the furnace.

In order that one scale car would be sufficient for the first two furnaces installed, it was designed to charge on either side. To make this possible the bottom plate B is suspended on a square shaft running the length of the body, and can be turned through 90° to dump on either side.

BLAST FURNACES

These furnaces (Figs. 5 and 6) are designed for the pyritic smelting of a charge which yields a low grade, highly corrosive matte, and which has a pronounced tendency to form accretions on the upper jackets. Another point aimed at in the design was to make the job of changing jackets as simple as possible.

Superstructure.—This is a comparatively light, all-metal structure. The walls are really jackets through which cooling air, drawn by the stack suction, enters at the inlets shown at A in Fig. 5, and passes out at the top. The roof, as shown in the drawing, consists of water-cooled C.I. plates, but after having seen the furnaces of the Tennessee Copper Company I would abandon the water cooling and cast these plates with radiator ribs.

The side doors are plates suspended from hinges at the top, and are forced open by the impact of the charge. The end door, through which any barring of accretions must be done, extends across the full width of the top, and is raised by the air cylinder B.

Furnace Shaft.—This is considerably deeper than the ordinary furnace to provide the high charge column necessary in pyritic smelting. There are two tiers of side jackets, and three

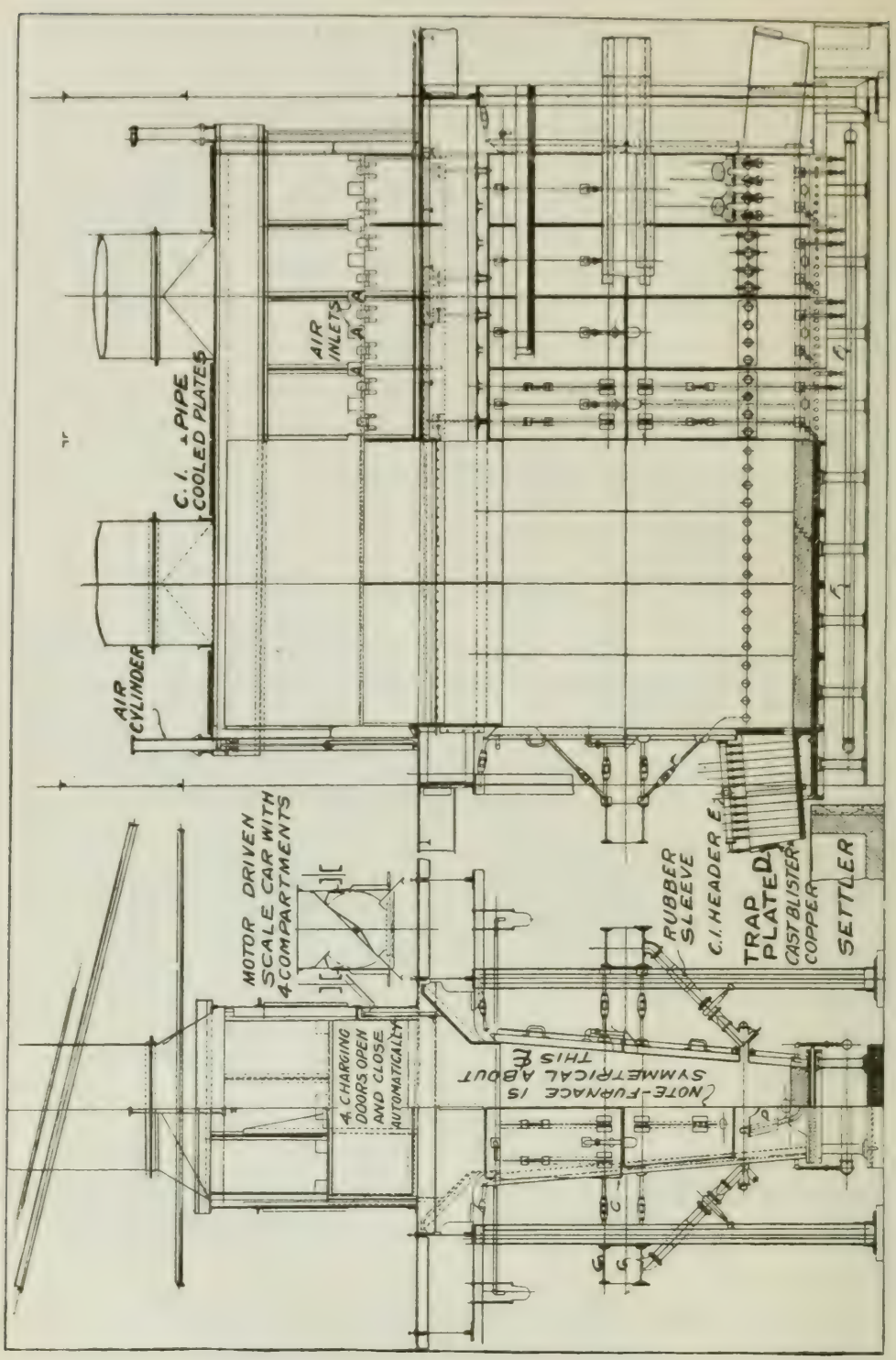

Fig. 5—Blast furnace.

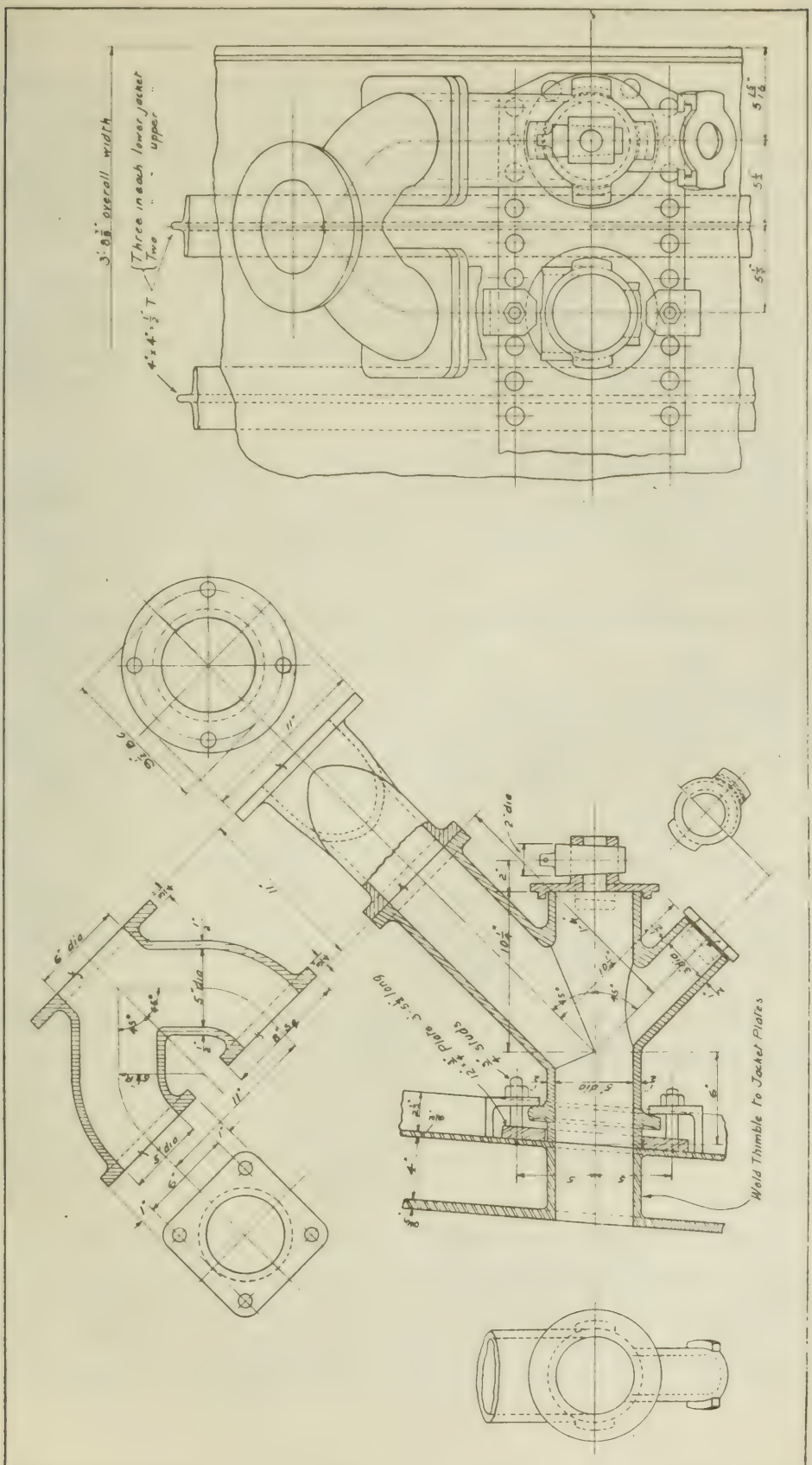

Fig. 6—Blast furnace tuyere.

tiers of end jackets including the breast plate. The inner face of the jackets is in profile a straight line. The upper end and side jackets are identical and interchangeable, thus reducing by one the number of jacket forms required. This construction accounts for the corner projecting at C.

If desired, a single jacket extending from the bottom plate to the top could be substituted for the upper and lower jacket. This would further simplify the water connections, and the absence of any horizontal joint between jackets might retard the forming of accretions.

The manner in which the jackets are held in place will be clear from the drawing. It will be seen that the bracing, piping, etc., are designed to facilitate the rapid removal or installation of any jackets.

Breast Plate and Connection Spout.—These are made of cast blister copper which, if water-cooled, appears to withstand the corrosive action of the matte for a long time. The spout is a launder sloping downward toward the settler. Across the discharge end is hung a trap plate D, which is adjusted to give the required trap to the blast. The inside of the spout is filled with clay up to the discharge level of this plate and when it becomes necessary to drain the furnace a hole is punched through this clay so that the drainage takes place into the settler. This makes it unnecessary to provide the emergency tap jacket and spout frequently seen on blast furnaces.

The cooling of the spout is provided by pipe coils cast in the blister copper. Each coil has a valve connection with the C. I. inlet and outlet headers E, and if a hole is burnt through a given coil, that coil can be shut off. This feature was developed by Mr. F. W. Draper, at a plant in Russia, and proved very satisfactory.

Water Supply.—In order to dispense with the excessive amount of piping generally found on blast furnaces the main F was placed in the position shown. Two very short branch mains are led from F, one to the bottom plate and one direct to the lower jacket. The water leaving the coil in the bottom plate

also enters the lower jacket. The overflow from the lower jacket passes through a single pipe to the upper jacket and thence to the overflow launder. With this arrangement, any mud in the jacket water will settle in the bottom of the lower jacket where it will do the least harm.

In case a single jacket were substituted for the two mentioned above, the pipe connecting the two jackets would of course disappear, and the water piping would then be a minimum.

Air Supply.—On most blast furnaces a round bustle pipe is provided, and, together with the usual girders, is a considerable obstacle to the removal of jackets. In this case the two beams GG are provided to brace the jackets at the points shown, and the bustle pipe is made by simply riveting plates to the flanges of these beams. The lower beam provides a flat surface to which it is very easy to attach the tuyere pipes.

There are four tuyeres to each jacket, with a tuyere pipe to each pair. The design of the tuyere box and the method of attaching it to the jacket are shown in Figure 6.

REVERBERATORY FURNACE

The furnace shown in Figs. 8 and 9 was designed to smelt 400 to 450 tons of charge and at the same time to act as a settler for 50 to 100 tons of converter slag. It is fired with pulverized coal. The emergent gases are to be led through waste heat boilers and will generate from 600 to 1000 boiler H.P. according to how hard the furnace is driven.

The drawings should be largely self-explanatory, and only a few brief comments seem necessary.

1. *Binding.*—Conforming with the modern tendency to avoid the large number of I-beam buckstays which used to be placed along the side-walls, this furnace is tied by 18″ I-beams set in pairs at 6′ 6″ centres. These are anchored by concrete piers at the bottom and tied across the roof with 2½″ rods.

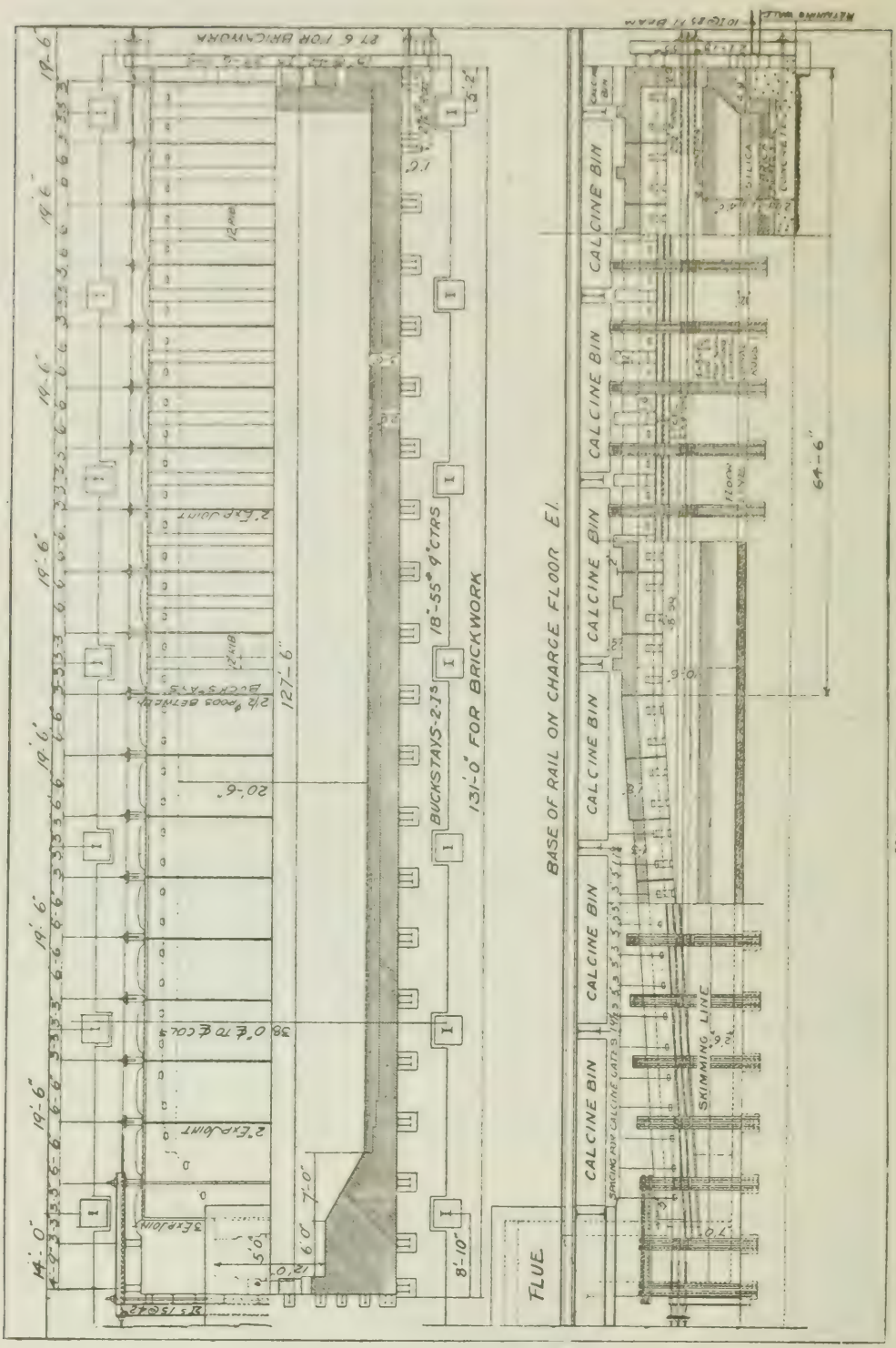

Fig. 8—Reverberatory furnace.

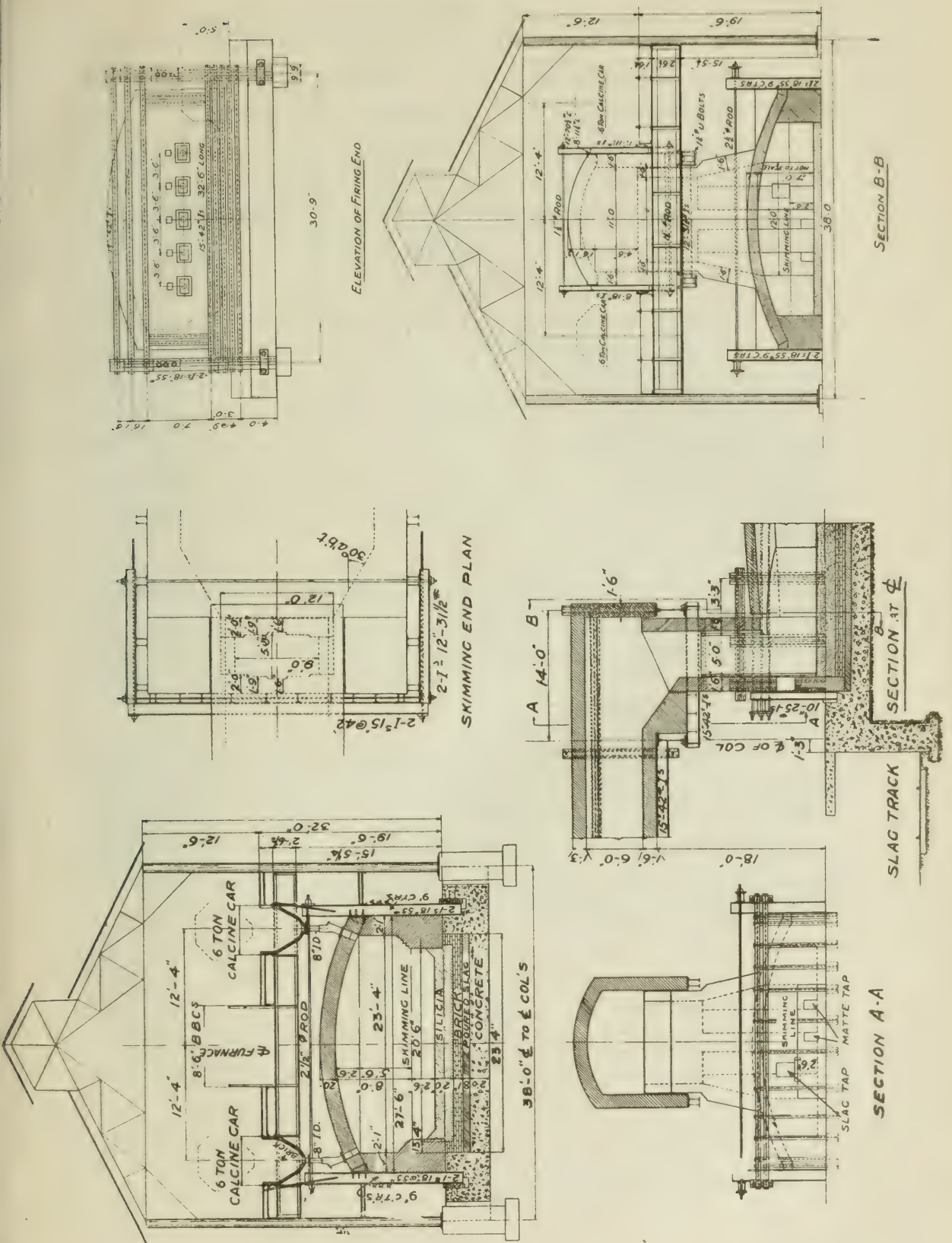

Fig. 9—Reverberatory furnace.

Between these buckstays are suspended ribbed steel castings, which serve as skewbacks to carry the arched roof.

The longitudinal tie rods are all carried outside the buckstays along the side-walls instead of over the roof and counteract the longitudinal thrust of the furnaces through buckstays against the end-walls. The absence of tie rods lengthwise over the roof makes it easier to clean and repair it.

2. *Roof.*—It will be noted that the roof has 12″ ribs midway between the expansion joints for the first 60 feet of its length. This feature, I believe, is a recent development in the west. It frequently happens that a small area in the roof gets very thin or burns through entirely, necessitating a more or less lengthy shut-down for repairs. When this happens with this furnace, a rough but rapid repair job can be effected by springing a brick arch lengthwise between the ribs.

3. *Uptake.*—The uptake, through which the gases leave the furnace telescopes into the overhead flue which is supported on steel and is quite separate from the uptake. This leaves the uptake free to expand and contract, and when necessary to be rebuilt without affecting the flue.

4. *Charging Facilities.*—The hoppers for calcine and fettling material run lengthwise and are discharged into the furnace through 8″ pipes and drop holes at 3′ 3″ centres. The calcine hoppers are brick lined to reduce the heat loss due to radiation. It is not universally realized how important it is to conserve the heat developed in the calcine by the roasting process.

APPLICATION OF PULVERIZED COAL IN BLAST FURNACES

By E. P. Mathewson and W. L. Wotherspoon*

(Annual Meeting, Montreal, March, 1919)

History of Early Attempts.—The use of pulverized coal in reverberatory furnaces, cement kilns, open hearth furnaces, boilers and other similar furnaces, has been dealt with extensively in many papers and publications; the present paper on the other hand will be confined to the application of pulverized fuel to blast furnaces, wherein the mixture of fuel and air is injected into the lower portion of a piled mass of material, and combustion takes place under pressure.

Until recently the history of pulverized coal in blast furnaces contained nothing but records of failures. Sir Lowthian Bell, in his book on the "Principles of the Manufacture of Iron and Steel" published in 1872, which deservedly ranks among the world's metallurgical classics, mentions an attempt to introduce finely divided coal with the blast at the tuyeres in an iron furnace; the attempt was soon abandoned, and Bell remarked that it needed but little consideration to insure the rejection of all such schemes.

About 1902, Mr. W. J. Forster, of Darlaston, England, satisfied himself by a great number of experiments at the Darlaston furnaces: "That nothing but failure can be expected from the addition of cold materials into the hearth of the furnace with the blast."

Possessed of this opinion, Mr. Forster suggested the use in the blast furnace of a specially prepared carbon obtained by heating solid carbon to a very high temperature, so that all volatile matter and moisture should be expelled and the carbon should be strongly heated before its use in the blast. He obtained British and American patents on the expedient of so preparing carbon and introducing it with the blast, whereby he hoped to make special grades of iron. The idea seems to have produced no effect upon the art of smelting iron, but it

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may be considered to illustrate the rest of the history of the use of pulverized fuel in blast furnaces, as this history consists of sundry comparable suggestions of expedients all of which have, so far as known, failed to meet with practical success. The efforts to use successfully pulverized fuel in iron blast furnaces have embraced such expedients as the substitution of heated gas, with and without super-heated steam, for some or all of the air; the careful classifying of the fuel into different and distinct sizes with a view of employing the finer grade to create a high initial temperature to ignite the rest; the substitution of an annular reverberatory arranged around the base of the charge, and the injection tangentially thereinto of the powdered coal and air; the grinding and mixing of the charge itself so that the particles might fall through a stream of burning fuel and air, and so on. It is not profitable for present purposes to consider all these expedients or the various patents which have been granted on them, because, so far as is known, none of them has been sufficiently successful to secure adoption.

The results obtained by the recent work which we shall now describe have been attained not so much by resort to extraneous expedients as by the development of the combustion process itself. The chemical phenomena of combustion are relatively little known, although they have been made the subject of important research work by numerous scientists since the days of Bunsen, who, in 1845, made investigations on a coal-fired blast furnace used for the smelting of iron ores; and it is impracticable, within the limits of this paper, to discuss these phenomena in detail. The phenomena apparently embrace distillation of volatile matter, gasification, and combustion. When a mixture of air and finely divided fuel is directed into and against a mass of more or less refractory material, different results may ensue, according to variations in a multiplicity of factors. The work to be described seems to demonstrate that by proper provision of suitable space for combustion, maintenance of correct air pressure and fuel supply within the combustion space, it is practicable to develop within the charge a sort of supercombustion, which provides at greatly reduced cost the heat

necessary to bring the charge to a molten condition. It is particularly difficult to generalize or define the possibilities or limitations of the generation of heat in a blast furnace so operated, for much depends upon the physical and chemical characteristics of the charge, as well as upon the variable factors directly entering into the combustion. A better idea of the work may be afforded by concrete illustration.

For this purpose we describe work in a field which, we believe, has heretofore been untouched even by suggestion, namely, the melting of copper and the smelting of copper ores.

Experiments of Garred.—Mr. Garred became interested in the application of pulverized fuel to blast furnaces in 1913, but it was two years later when he applied some of his ideas in a practical way, by melting blister copper in a blast furnace as shown in Figs. 1 and 2. The design provided special facilities for combustion, and the tuyeres were so arranged that in the event of the charge becoming frozen, they would remain clear. During the experiment, over a million pounds of blister copper was melted.

The experiments were particularly interesting owing to the fact that with a furnace of 36 in. diameter, handling large angular pieces of blister copper, it was possible to continue the work to the extent described. Observations taken during a test run are shown on Fig. 3.

In connection with the danger of a charge becoming frozen it might be mentioned that the furnace was allowed to stand over a week end, and was then successfully restored to its normal condition in a short time, by the use of pulverized fuel.

Experiments at the Tennessee Copper Company's Smelter.—Experiments at the smelter of the Tennessee Copper Co. were decided upon early in 1918, one of their standard blast furnaces, 22 ft. 6 in. long by 60 in. wide, being used. Ten tuyeres on one side of the furnace were equipped for the use of pulverized fuel, and the first test run of importance started on April 22nd and was continued until May 4th, during which period the

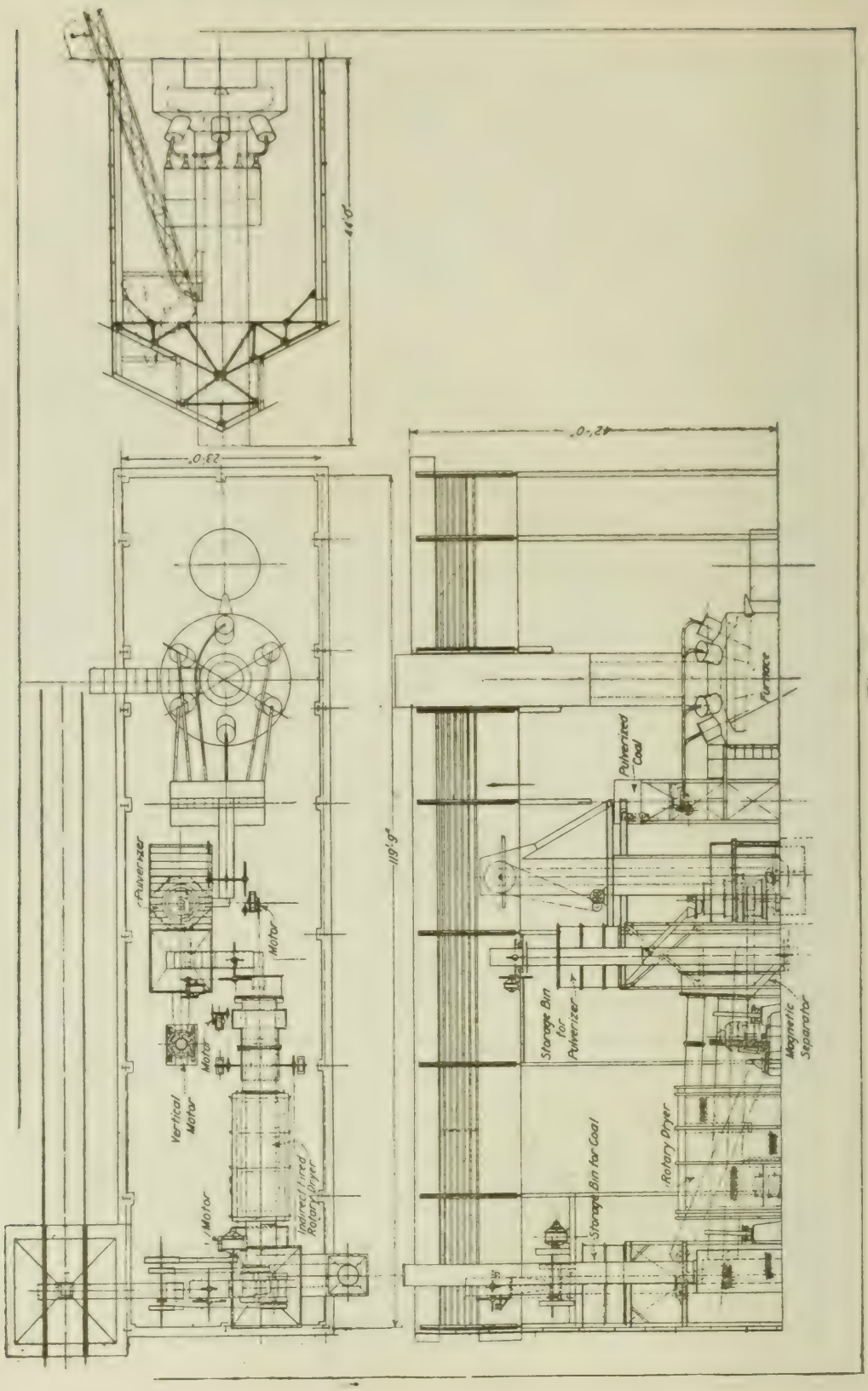

44'0"
23'0"
Pulverizer
Motor
Motor
Vertical Motor
Motor
Indirect Fired Rotary Dryer
119'9"
Pulverized Coal
Furnace
Storage Bin for Pulverizer
Magnetic Separator
Rotary Dryer
Storage Bin for Coal

Fig. 1

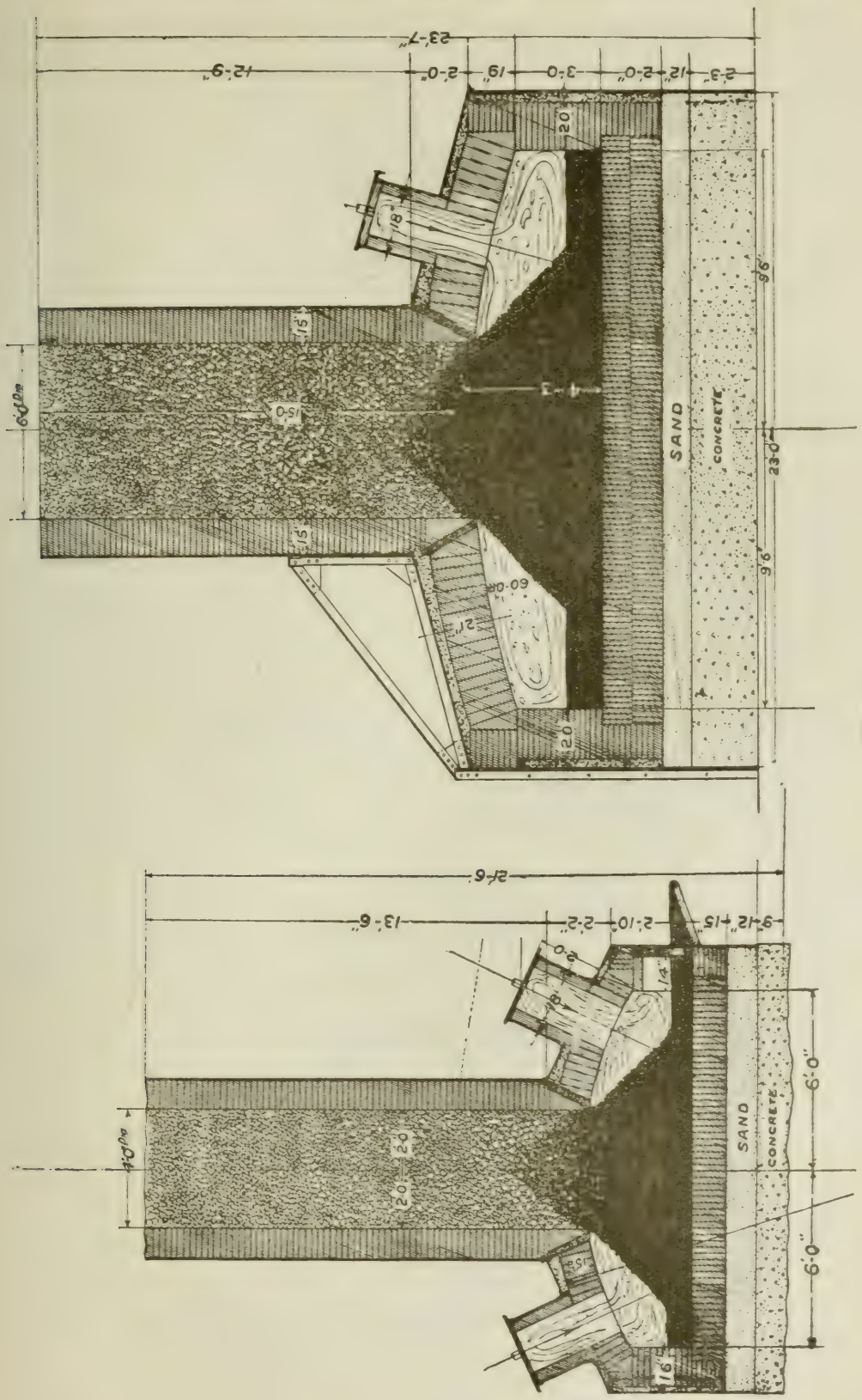

23'-7"
12'-9"
2'-0"
19"
3'-0"
2'-0"
12"
2'-3"
20'
18"
15"
15'-0"
SAND
CONCRETE
9'-6"
23'-0"
9'-6"
60'-0"
21"
20'
27'-6"
13'-6"
2'-10"
2'-2"
9'-12"
15"
2'-0"
14"
6'-0"
SAND
CONCRETE
20'—22'
15"
6'-0"
18"

Fig. 2

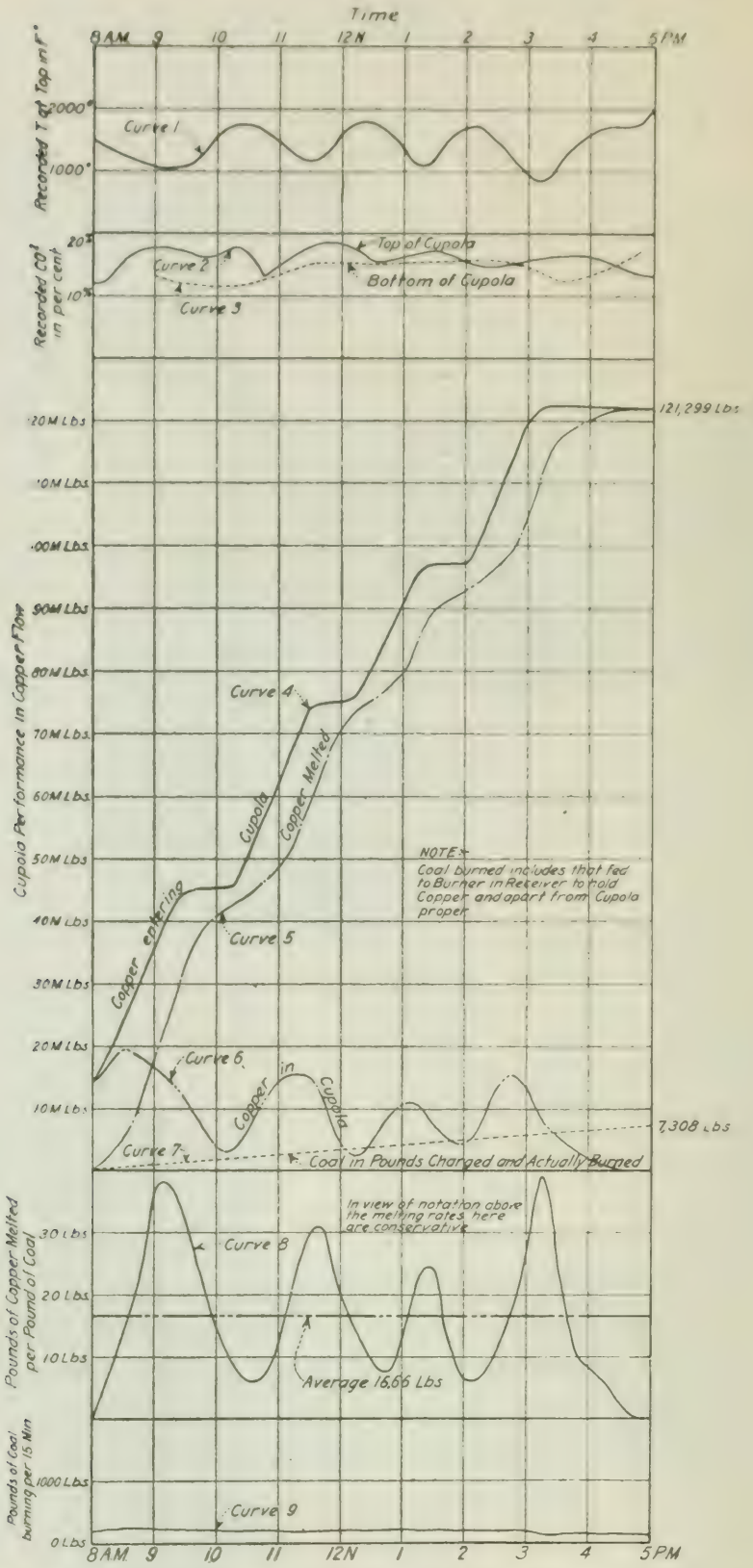


Chart showing operations *re* experiment melting blister copper.
Fig. 3

percentage of coal to the charge was 3.8 as against 5.7 of coke used on the other furnaces during the same period, when operating with a similar charge. The second test run started May 9th, and continued until May 24th, when the percentage of coal used was 3.6; a very small amount of coke being used intermittently.

A third test run was then made, feeding a little coke on the side of the furnace where no coal was fed previously, as it had been found there was a tendency for crusts to form on that side of the furnace. It was then decided to apply the coal at ten tuyeres on each side, but experimental work was postponed, owing to the possibility of some unconsumed carbon in the furnace gases causing discolorization and affecting the quality of the acid, which is an important product of the company, particularly during the war, when a portion was used in the manufacture of high explosives. The war requirements in this connection no longer existing, the company returned to the experimental work in January, and are continuing, with various modifications, the methods of applying the coal.

As the Tennessee Co. had not used pulverized coal previously, it was necessary to install a coal preparation plant. A plant with a capacity of three tons per hour was constructed at a cost of about $35,000. The cost of the feeding apparatus at the furnace was about $5,000.

An analysis of the average ore smelted at Copperhill, Tenn., during 1918, is as follows: Cu. 1,55%; Fe 34.6; S. 24.6; SiO_2 20.3; CaO 4.9; MgO 2.0; Zn 1.4; Al_2O_3 4.3.

The furnace has 27 tuyeres on one side and 24 on the other and the air blast is maiatained at 35 to 45 ounce pressure.

Fig. 4 presents a general arrangement showing the method of applying pulverized fuel to the experimental furnace.

Experiments at the International Nickel Company's smelter at Copper Cliff, Ontario.—Following the work of Garred, already described, the International Nickel Co. decided, in June, 1918, to carry out experiments in the blast furnace

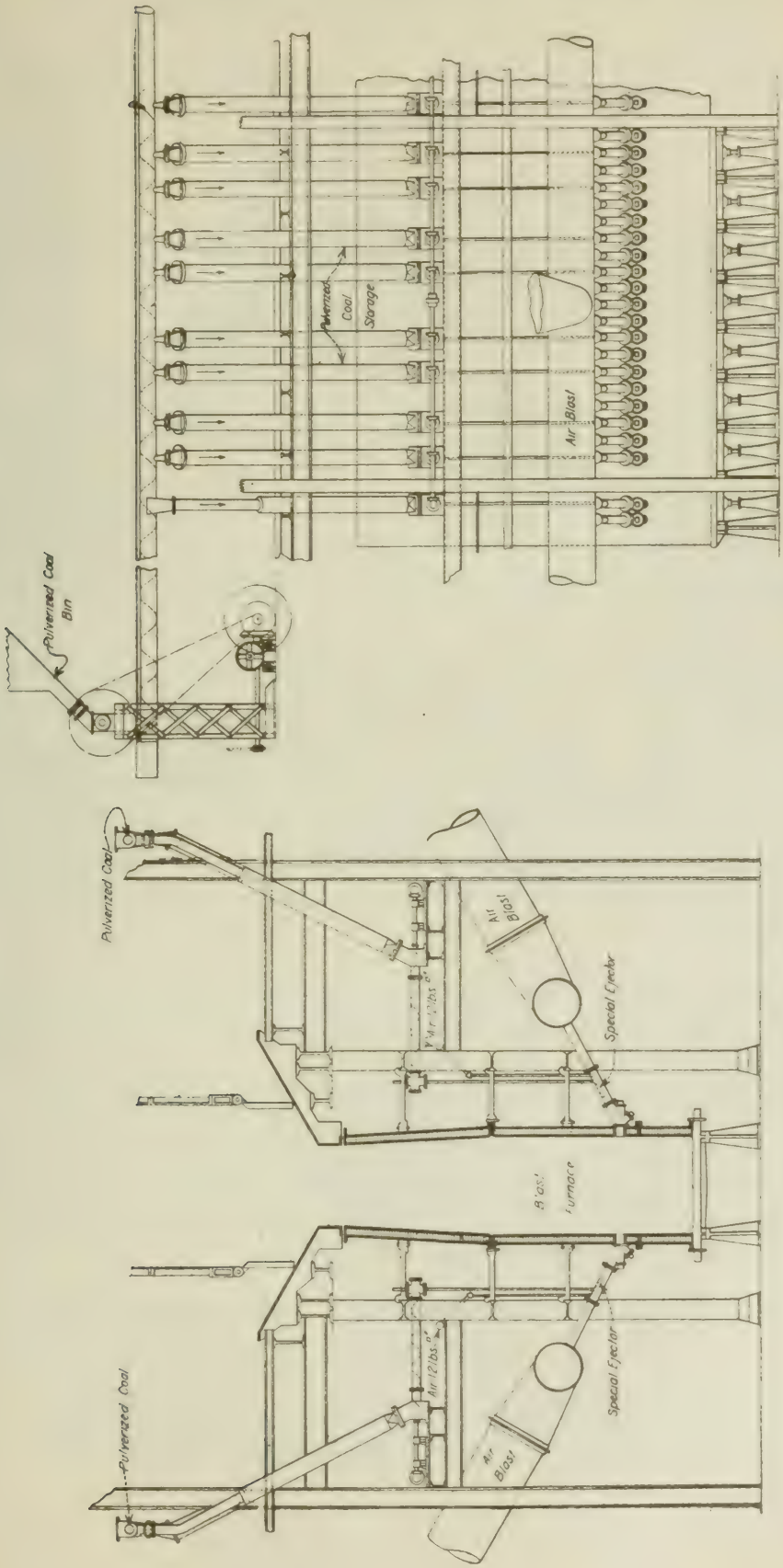
department of their smelter at Copper Cliff, Ontario. It was decided to utilize one of their standard blast furnaces, which are 25 ft. 6 in. long by 50 in. wide. The furnace bottom is lined with magnesite brick to within 14 inches of the centre of the tuyeres; the two lower rows of jackets are cast iron with water-cooled pipes, and the two upper rows of jackets are of the standard water-cooled steel type. The furnace has 48 six-inch tuyeres, 24 on a side, spaced about 12 inch centres. These are connected to a main bustle pipe with 6 inch galvanized branch pipes fitted with canvas sleeves. The bustle pipe is supplied, by an offset, from the main delivery pipe which feeds seven other furnaces, the normal pressure of air carried at the tuyeres being 23-24 ounces.

The furnace charge consists mainly of a refractory copper-nickel sulphide ore, a large proportion of which is delivered from the company's roasting plant. The composition of the charge and the average size and analysis of the constituents and products are as follows:

	Percentage of charge to blast furnace. Av. 6 months.
Roast ore	74.8
Raw Creighton	2.8
Raw Crean Hill	8.0
Total ore	85.6
Converter slag	10.2
Converter scrap	3.2
Limestone and Quartz	1.0
	100.0

Screen Tests.

Roast ore—on 1½"....53%
Roast ore—on 1"....16%
Roast ore—through 1"....31%
Raw Creighton, practically all through ¾".



Diagramatic view, coal dust feed copper furnace
Fig. 4

TYPICAL COMPOSITION OF BLAST FURNACE CHARGE AND PRODUCTS

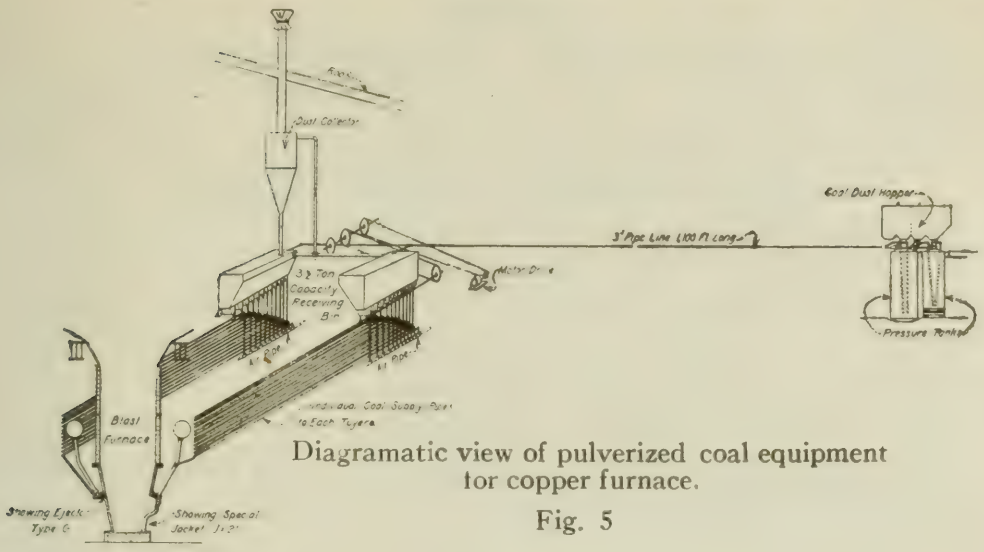
	Cu.	Ni.	Fe.	S.	SiO_2.	Al_2O_3.	CaO.	MgO.
	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.	P.c.
Roast ore.....	1.40	4.10	38.50	11.75	20.25	4.50	2.25	2.50
Raw Creighton ore.	1.40	3.90	39.50	23.00	21.00	5.25	2.50	3.00
Raw Crean Hill ore.	2.50	1.75	24.00	11.50	32.00	10.00	5.00	5.50
Converter Slag.....	1.00	3.00	47.00	2.40	26.75	3.00	1.25	1.50
Scrap charged.....	2.25	6.00	42.00	2.00	21.75	2.00	.75	1.50
Limestone.....	....	....	1.00	....	2.50	....	52.75	1.10
Quartz.....	....	....	3.00	....	91.00	2.90	1.00	1.00
Bl. Fur. Matte.....	5.85	14.35	48.40	26.25	(6 mos. avg.)			
Bl. Fur. slag.....	0.16	0.32	40.90	1.65	33.15	6.50	3.70	2.50

The furnace, under normal conditions of smelting, treats about 500 tons of charge a day, utilising 60 tons of coke; the average coke consumption for six months being 12.5 per cent of the charge.

Regarding air conditions, only approximate estimates were available, owing to the whole of the blast furnace plant being supplied from a central blower installation. General observations indicated that the furnace charge is kept about seven feet deep, and the smelting zone is from two to three feet above the tuyeres. Blow holes form quickly after a fresh charge, but the amount of dust made is about normal, viz., 1.5% to 2.0% to the ore.

The tuyeres require punching regularly, the method being to remove the tuyere cap, and by introducing a rod, to ease the ore in the vicinity of the tuyere. It was usual, when cleaning these tuyeres, for some loose ore to be blown out on the furnace floor in a condition which indicated that the ore close to the tuyeres had not been strongly heated. Through the tuyeres, the charge appeared black and usually there was no appearance of fire until near the middle of the furnace.

The usual practice is to make up a furnace charge consisting of certain proportions of roasted ores, green ore, by-products, such as converter slags, and coke—all being dumped into the top of the furnace from small cars in such a way as to give an even distribution in the body of the furnace. Under these con-



Diagramatic view of pulverized coal equipment for copper furnace.

Fig. 5

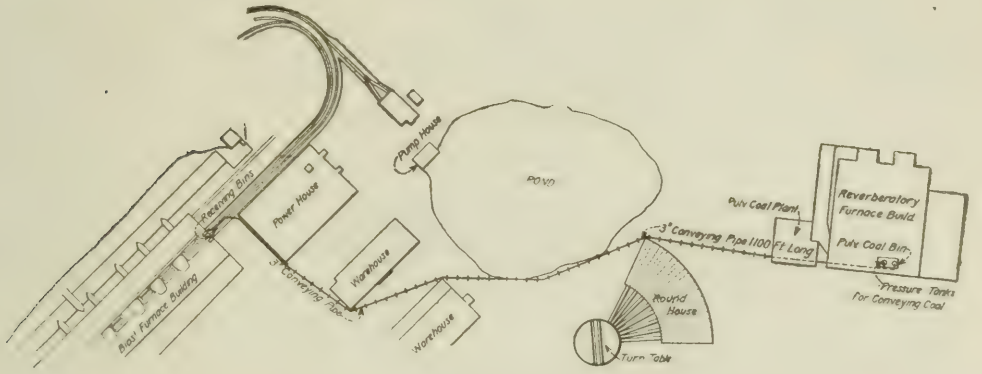


Fig. 6

ditions of intermittent charges of the fuel, the regularity of its distribution is not easily obtained.

Arrangements for conducting the experiments were greatly facilitated because the company had utilised pulverized coal in reverberatory furnaces since 1911. The coal preparation plant, however, was 1,100 feet from the blast furnace, and the first problem was how to transmit the coal (Figs. 5 and 6). Attempts were made to transmit the coal in pipes by means of ejectors, but although the results obtained were interesting, they did not meet the particular problem satisfactorily.

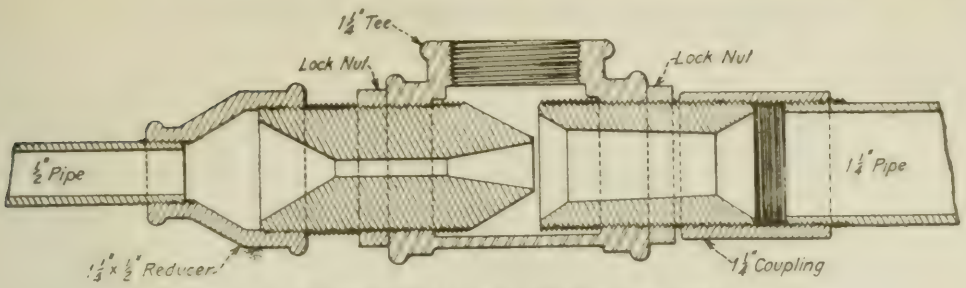
Compressed air was then used for displacing the pulverized coal from storage tanks, and it was found that 2½ tons of coal

could be transmitted in five minutes through a 3-inch standard wrought iron pipe, 1,100 feet on the horizontal and with an elevation of 50 feet.

The feed or service bins at the blast furnace are about 13 feet long, 3 feet wide at the top, 14 inches wide at the bottom, and about 6 feet deep. They are constructed of No. 14 gauge steel plate, and are completely closed, a manhole being provided, and an air vent pipe to which a cyclone separator is fitted. The bins each hold about 3½ tons of pulverized coal. At the bottom of each are twelve common screw feeders, operated from a line shaft through bevel gears, each feeder having a small clutch; the line shaft being driven from a variable speed motor. The feeders can be operated satisfactorily at speeds between 40 and 100 rpm., to deliver from 3 to 6 pounds of coal per minute; and any individual feeder can be stopped without interfering with the general operating conditions. The screws are made of special length and pitch, being made in a lathe, and in calibrating these at different speeds for the discharge of the coal, no flushing effects have been noticed. This arrangement of feeding the coal is positive, sufficiently accurate and mechanically simple. The twelve feed screws at each bin discharge the coal into 1¼ inch diameter pipes which are in turn connected with the blast pipes or tuyeres at the furnace, the coal being transmitted by ejectors, using a small quantity of high pressure air, which is beneficial in the mixing of the fuel and air for the furnace.

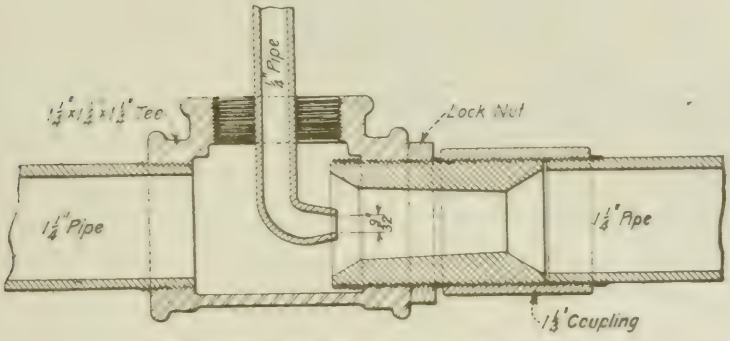
Experiments have been made with a number of ejectors, the design of which is important, when giving consideration to economy in the use of compressed air. Easily constructed ejectors may be made from standard pipe fittings, by proportioning the sizes, but the size and proportion of the inlet of the compressed air to the discharge of the ejector is a most important feature. Some of the ejectors used are shown in Fig. 7.

In commencing the experiments the air blast for the combustion of the coal and for smelting was furnished in the regular way under normal operating pressure, and the pulverized coal was introduced directly into the blast before entering the tuyere.



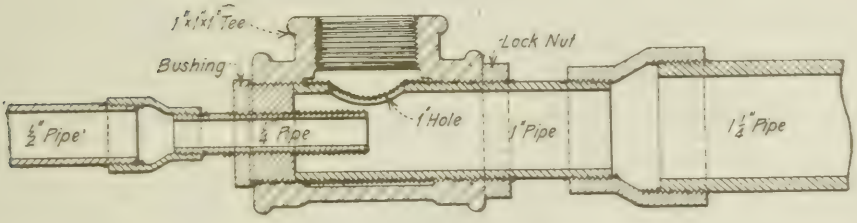
75# Air Delivers 4 Lbs Coal Against 2 Lbs Pressure

EJECTOR A



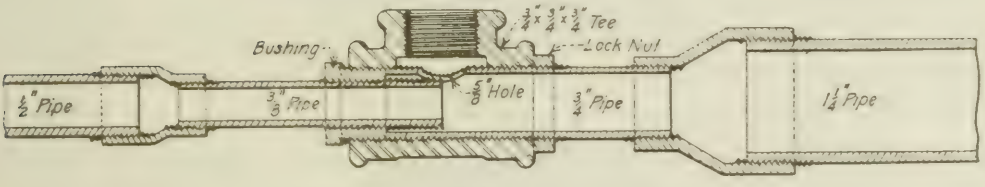
65# Air Delivers 4 Lbs. Coal Against 2 Lbs. Pressure

EJECTOR B



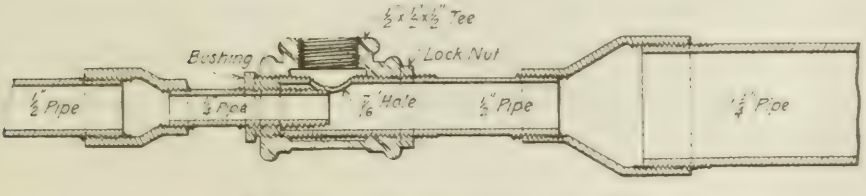
40# Air Delivers 4 Lbs. Coal Against 2 Lbs Pressure

EJECTOR C



30# Air Delivers 4 Lbs. Coal Against 2 Lbs. Pressure

EJECTOR D



15# Air Delivers 4 Lbs Coal Against 2 Lbs Pressure

EJECTOR E

Fig. 7

It was found that the coal could be introduced very rapidly in this way while the furnace had its regular charge of coke and ore, but when the coke was cut below 50% of normal, it was found that the tuyeres became closed, coal dust would lodge in the tuyere pipes, and a certain quantity would find its way into the bustle pipe, causing trouble at any leaky joint, thus rendering the condition around the furnace more or less dangerous. At this time the joints between the furnace jackets and the tuyeres were not as tight as they should be, and there was considerable leakage of coal dust. Tuyeres of several designs were tried to avoid leakage, and the canvas sleeves on the branch pipes were replaced with 5-inch standard pipes, having flexible joints. Improved results were obtained in this way, and some of the tuyere used are illustrated in Fig. 8. Later on, the coal was introduced to the blast by means of an ejector like that used by Mr. Cavers at the Tennessee Copper Company.

During this stage of the experiments, the main troubles were at the tuyeres, which required regular punching, and there was some leakage of coal. The coal was applied to only half the tuyeres on each side of the furnace, being introduced to alternate tuyeres, those on the front of the furnace being staggered in relationship to those at the back. Mr. Garred experimented with check or explosion valves which were placed in the branch pipes. It was found these check valves were not effective except when they were carefully designed and placed in every branch pipe, and this was a complication of apparatus that was not considered desirable. It was then found that if any individual tuyere was choked, the coal was drawn into the bustle pipe by suction and found its way down the branch pipes leading to tuyeres that were open. It was therefore agreed that any possibility of explosions could be effectively prevented by arranging check or explosion valves in the bustle pipe itself. The experiment was then made of introducing the coal between and slightly above the tuyeres, by boring a hole through the jacket and connecting to these the coal supply pipe from the ejectors at the screw feeds, thus introducing a dense mixture of coal and air into the furnace independent of the

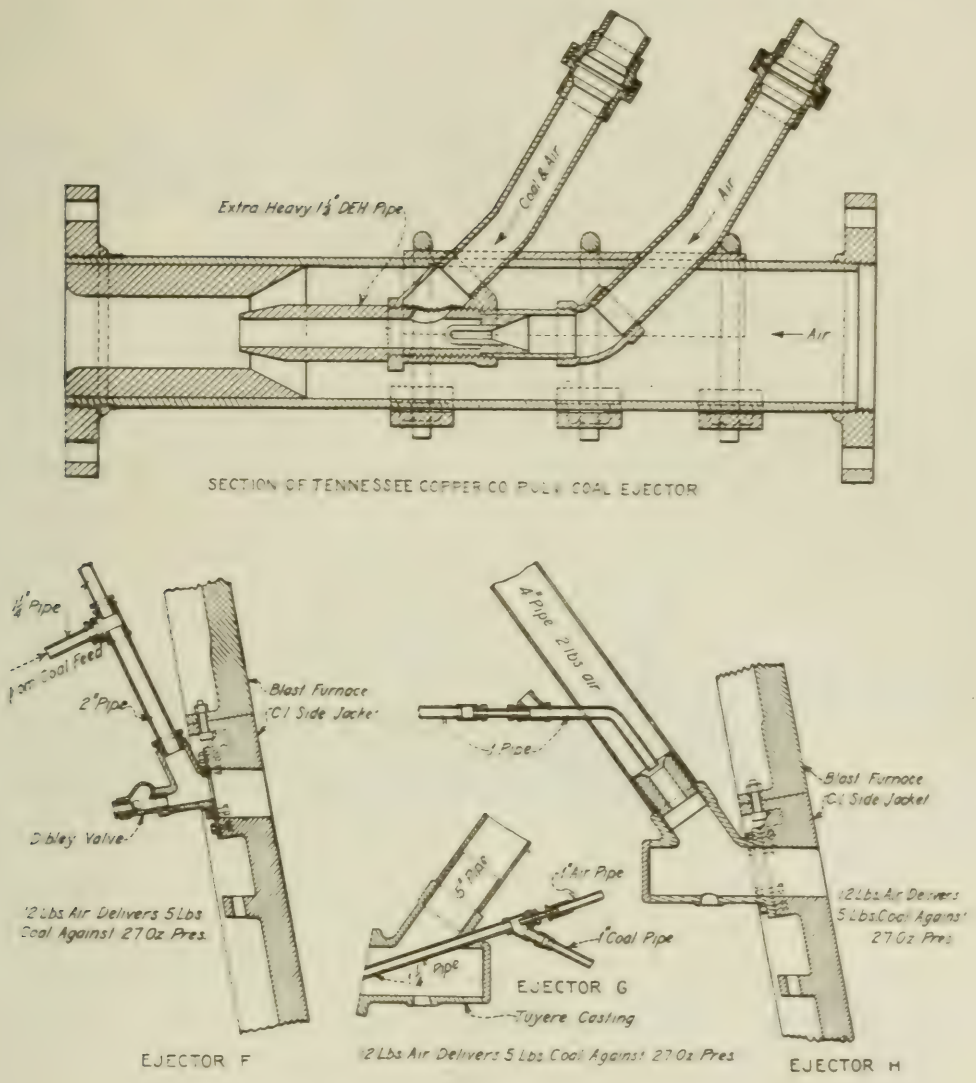
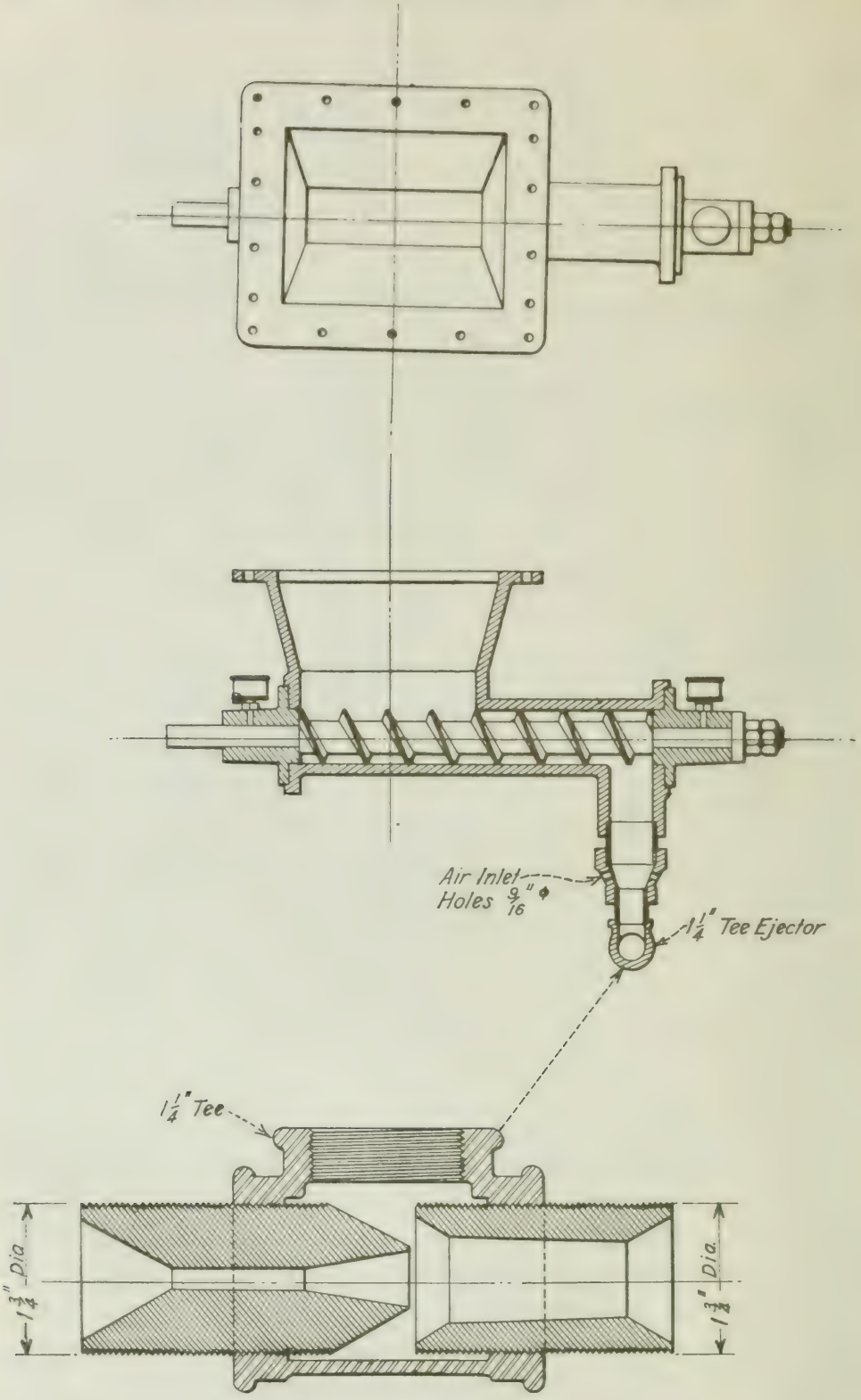


Fig. 8

main air supply. This was found to be a clean method and a test was made over a period of eight days. During this time the coke was reduced from 12% to about 6%, with promising results; the most important and necessary condition still being that of keeping the tuyeres open. It was observed that the small openings (1½ in. pipe) through which the coal was introduced into the furnace required very little punching, the main trouble being with the large tuyeres; and by observation through



1¼" TEE EJECTOR
FOR COAL FIRING EXPERIMENT
Fig. 9

the Dyblie valve, the combustion and the smelting of the ore in the furnace could be seen in operation.

It was decided to use specially designed furnace jackets at the tuyere level of the furnace. The design finally adopted is shown in Fig. 10.

These jackets, it will be seen, provide means for a more even distribution of the blast, and it was thought that they would give better opportunity for combustion at the entrance to the charge. It was also believed that furnace jackets designed on this principle would not be more expensive than those of regular design, as two tuyere castings with their joints and machine work

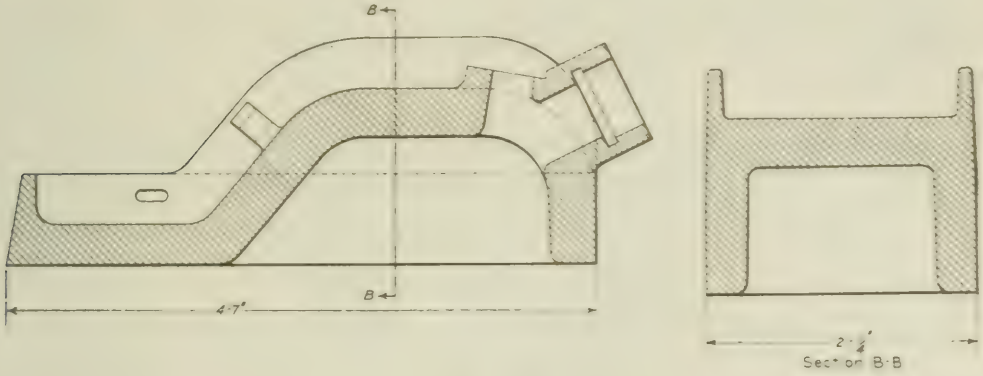


Fig. 10

would be dispensed with. The furnace is now equipped with some of these jackets, but it is too early to state, definitely, how advantageous they are.

Experiments have been made with a standard blast furnace reduced in width from 52 inches to 36 inches at the tuyere level, with the air blast at various pressures, and melting a variety of furnace charges. Considerable study has also been given to modifying the design of furnaces in order to obtain ideal conditions in smelting. Fig. 11 illustrates one of these modifications, which it was found could be easily obtained by changing the section of the jackets in the existing furnace at the International Nickel Company's smelter. These modifica-

tions, it is believed, will be advantageous for the following reasons:—

1. There will be produced, mechanically or artificially, a condition wherein the melting zone is fixed in proper relation to the combustion and charge.

2. The tuyeres will be free and unobstructed, giving improved conditions with reduced costs.

3. The most efficient use of air blast will be possible, on account of its complete control, regulation and distribution.

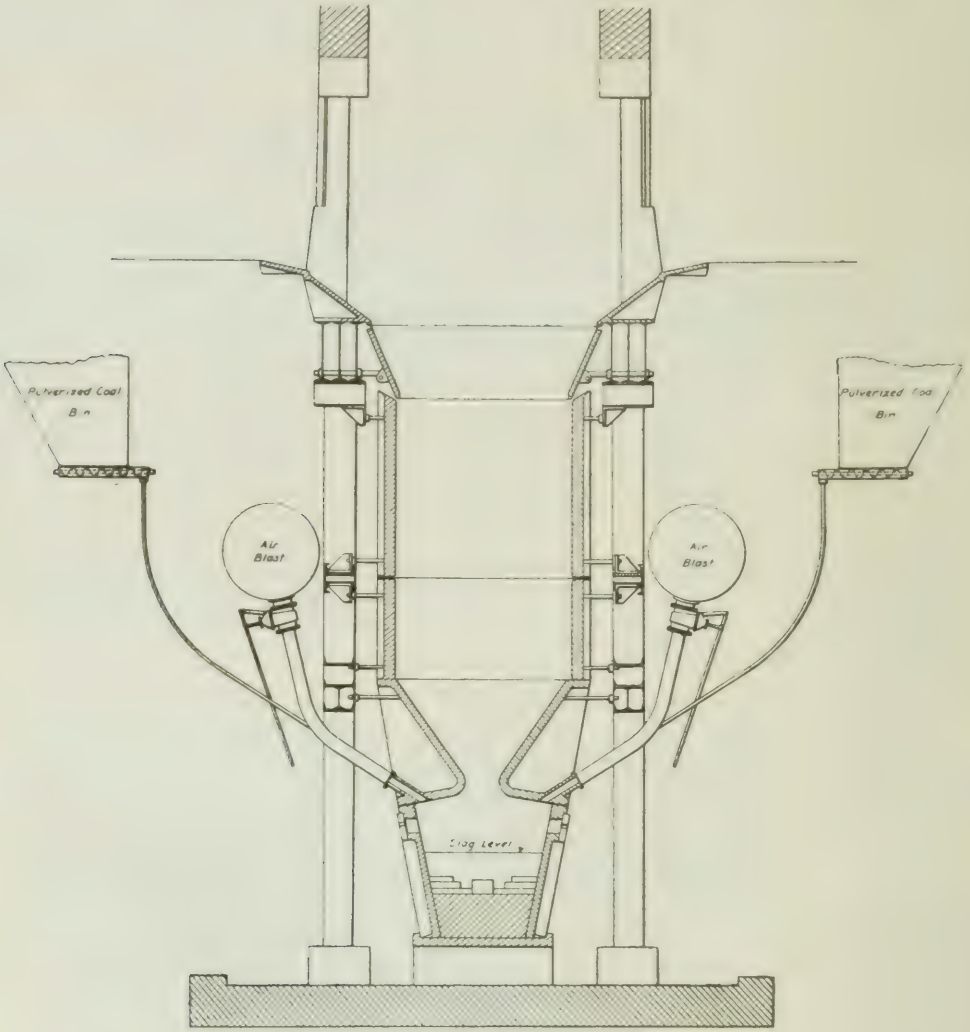


Fig. 11

4. There will be a combustion chamber and tuyeres so arranged that any gaseous fuel can be used efficiently; among such gaseous fuels may be included pulverized coal and atomized oil.

5. The furnace construction will cause the gases from the combustion chamber to be distributed efficiently to the furnace charge. Combustion arrangements are such that positive ignition of all the fuel is assured.

6. The molten mass in the crucible will be strongly heated to facilitate the separation of the metals.

7. The furnace construction can be so arranged that concentrates, flue dust, fines, etc., can be smelted economically and with minimum losses by being introduced into the lower part of the furnaces by means of the tuyeres or other suitable connections.

8. There will be the utmost economy in the use of air blast, with resulting economies in power, and there will be a greater efficiency in the use of oxygen, due to the pre-heating of the gases and their better distribution.

9. The furnace may be rectangular or circular, with the melting zone arranged correspondingly.

10. With a furnace of this design, combustion occurs at the base of the furnace charge, thus obtaining the most efficient use of the heat and gases.

11. The furnace design provides facilities for repairs to the lower portion of the furnace without resorting to the usual procedure of shutting down and digging out the whole of the furnace charge.

To summarize the results of the experiments at Copper Cliff, it can be said that under difficult conditions, and without interfering with production in the slightest, it has been demonstrated that important economies are possible at many smelting plants by the utilization of pulverized coal, thus replacing a considerable portion of the coke, and the International Nickel Com-

pany, early this year, decided that an aggressive policy of experimentation and development should be followed.

Influence on Operating Conditions and Costs.—It is a foregone conclusion that the characteristics of the charge will have an important bearing on the results obtained. At Tennessee the charge consists of run of mine ore and quartz in large pieces, with a high percentage of sulphur, and melting conditions that call for relatively small quantities of fuel. At Copper Cliff, the ore is comparatively fine, over 74% of the charge coming from the roasting beds from which it is reclaimed and handled two or three times, and the final sulphur content does not much exceed 12%.

There are some blast furnaces operating in conjunction with reverberatory furnaces, where the blast furnace charge is favourable for easy smelting conditions, due to the slags and other by-products being treated therein. It is generally believed by those conversant with the experiments that successful work at Copper Cliff can assuredly be followed by successful work in a large proportion of the blast furnaces smelting non-ferrous ores elsewhere.

Regarding blow-holes in the charge, it appears that these should be less when utilizing pulverized fuel than under normal operating conditions, as segregations of the coke are, to a large extent, responsible for the blow holes. For the same reason, beneficial results might also be anticipated regarding dust losses.

It is often stated that large pieces of incandescent coke are necessary in the charge to support the burden. This may be so under certain conditions, but the experiments indicate that it is not essential in smelting copper sulphide ores, and we do not expect it to be a matter of great moment when treating other non-ferrous ores.

Another point of great importance is the effect of the Garred-Cavers process on the tuyeres and the amount of tuyere punching. Tuyere punching, under normal conditions, entails a good deal of hard labour, and it is our opinion the conditions in this

connection will be greatly improved. The moisture content in the charge may be high without causing trouble; during the experiments several charges of wet fines, the clean-up from storage bins, having been handled without trouble.

In the preparation of pulverized coal it is customary first to reduce the run of mine product, when this is used, to about one inch in size, preparatory to drying, and then to reduce the powder in pulverizers. The first precaution should therefore be to remove any iron or steel from the coal, by means of magnetic separators.

The next precautionary measure is to employ a type of dryer that does not allow the coal to accumulate in large settling chambers; to guard against overheated bearings, and to have the dryer fired and controlled in such a manner that its temperature is under control at all times. It is also important, in arranging conveyors and elevators, to see that pockets and other spaces are not left for the accumulation of pulverized coal.

Coals high in sulphur and moisture content are liable to spontaneous combustion, and it is therefore advisable that bins should be made of metal, totally enclosed, with no corners or pockets where the coal is likely to lodge and stay for any length of time. Storage capacity should be as small as possible, compatible with uninterrupted service.

Danger of explosion occurs when the atmosphere is charged with finely divided fuel, and overheating, through accidents or negligence, causes combustion. It is claimed that sparks alone will not ignite the coal dust air mixture.

Pulverized coal is much safer than oil or natural gas, as a leak is easily detected by the eye, and the trouble can be quickly remedied. The entire system, from the point where the coal is dried, to the tuyeres at the furnaces, can be entirely enclosed, and the bins and conveying system contain but a small quantity of air, so that the danger of explosion is negligible.

It is a safe and good practice to blow pulverized coal through comparatively small pipes, and there are several successful installations, where the fuel is transmitted long distances by the Bonnot system; the coal being carried in suspension, with about one-third of the volume of air necessary for combustion.

With blast furnace tuyeres in good condition for operating there should be no risk of explosion, but check and relief valves should be installed to guard against such a contingency, in the event of interruption of the blast pressure. Automatic controllers should be used to stop the coal feed under such circumstances.

Regarding the ratio of furnace capacity to hearth area, it is too early to state anything definite.

There is consumed, in the United States, about ten million tons of pulverized fuel per annum, and its use is still further being increased, so there is now an established practice in the preparation of the fuel.

The most important influence on operating costs is in connection with the fuel utilized, the normal practice being to use coke alone, whereas these experiments show that coke can be replaced, to a large extent, by pulverized coal. The relative costs of coal and coke vary a great deal, but, on the average, coke may be stated to cost twice as much as coal delivered at the smelters. It is only necessary to refer to the fuel conditions in Canada to appreciate this phase of the problem. For instance, the International Nickel Company of Canada, Ltd., consumed, in connection with their blast furnace plant at Copper Cliff, during the last few years, about 300 tons of coke per day, the average cost of this product being (during the fiscal year of 1915-16) $6.25 per ton. The price of high grade bituminous coal, as used by them in connection with reverberatory furnaces, had a corresponding cost of $3.50 per ton of slack. Up to the present, high grade bituminous coal has been used in the experiments. The average analyses of this coal during the month of August, 1918, which average may be said to be fairly representative, was: fixed carbon, 51,85%, volatile matter 36.10%, ash 12.05%, and sulphur 3.28%—fineness 93% to 94% to pass a 100-mesh screen, and 75% to 85% to pass a 200-mesh screen. It will undoubtedly be possible, however, to develop the use of a large variety of pulverized fuel for blast furnace operations, as has been the case with boilers and other types of furnaces. Lignite will be suitable in many localities, among which are certain portions of Canada, Mexico and Burma.

In blast furnace smelting of copper ores, the ash content of the fuel is of minor importance, and the more erosion in a furnace charge the greater the efficiency, so that these two factors connected with the use of pulverized coal, which are discussed so freely in connection with other furnace applications, are here of little significance. The influence on power costs should be favourable, owing to the increased efficiency in the furnace, and the possibilities of more regular charge, reducing the wastage of air. The amount of power used for applying the coal at the furnace is small, being confined to the feeders and other apparatus, such as ejectors, etc. The air supply will naturally vary according to the character of the furnace charge and the height of the column that is found to be advisable. The present work has been carried on with the same air pressure and the same height of charge as is usually employed at these smelters; but if higher pressures are utilized, it is anticipated that the additional cost of power will be more than met by the increased efficiency in the smelting operation.

The introduction of the fuel at the tuyeres gives considerable relief on the charge floor of the furnace, and in a large smelter, should have favourable effects on the cost of tramming; the coke being usually handled in cars or other mechanical devices, from storage bins, and this requires an appreciable amount of labour, power and equipment.

The cost of preparing pulverized coal will vary considerably, as there are several factors bearing on the matter, among which are labour, power, fuel for dryer, repairs, in addition to interest and depreciation on buildings and equipment.

The power required for crushing, drying, elevating and conveying the pulverized coal will be about 20 horse-power hours per ton of coal handled, and with modern equipment under average conditions, the cost will be about eight cents per ton per hour.

The cost of operating the dryer will depend upon the cost of the fuel, as the amount required per ton of coal dried, with a given moisture content, with standard dryers, will not vary much.

The cost of labour will be directly affected by the equip-

ment installed and the size of the plant. The costs from several plants, with a capacity of from 5 to 10 tons per hour, varies considerably. The records for 1912, at the American Iron and Steel Manufacturing Co., of Lebanon, Pennsylvania, show 40c. per ton for the actual preparation of the coal, on a basis of 150 to 200 tons per day, and 20c. for the conveying system, which, in their case, is of an extensive character, owing to the large number of furnaces to which pulverized coal is applied. The details are as follows:

	Rate per ton of coal produced.
Fuel	$0.034
Repairs to buildings	.002
Operating	.145
Power (steam and electric)	.221
Repairs to machinery and equipment	.200
	$0.602

At the International Nickel Company's smelter, the average cost of preparing and delivering the coal to the furnace in 1913, was as follows:—

Labour	$0.15
Power	.10
Repairs	.145
Coal for drying	.055
	$0.45

The present costs are abnormal, due to war conditions, and will undoubtedly be reduced in the near future. They are as follows:—

Labour (6 months)	$0.384
Power (June to Nov., inc., 1918)	.084
Repairs	.284
Coal for drying (101 tons per day average)	.108
	$0.86

In this connection it may be stated that the cost of drying is excessive, because the moisture content of the coal averages about 10%, and that the amount of labour employed could conveniently prepare a much larger tonnage of coal.

The item 'repairs' includes all repairs to coal crackers, grinders, conveyors, fans, belting, etc. Four men on an 8-hour shift are all that are necessary to prepare and deliver 100 to 200 tons per day.

The costs in connection with lignite are, of course, greater than with other fuels, due to the large increase in dryer costs on account of the moisture. This, to a certain extent, is compensated for in reduced repair cost to pulverizing machinery, as lignite is easily ground. Some of the average operating costs, under recent conditions, are reported as follows:—

Small plants (2 to 5 tons per hour), $1.20 per ton.

Medium plants (10 to 15 tons per hour), 75c. per ton.

Large plants (20 tons and over per hour), 45c. per ton.

The preparation of lignite calls for more attention than that of other fuels, on account of the high moisture content, which is frequently in excess of 50%, and on account of the large amount of volatile constituents. It is usual to reduce the moisture to about 6%; to attempt further reduction is to invite trouble in the way of fires and excessive dryer costs, and all to no avail, because it will again absorb this much moisture from the atmosphere. Various tests show that lignites lose 2¾% of their volatile combustible matter, when exposed to a temperature of 284° F. for a period of thirty minutes. Such losses cannot be allowed, and so the drying must be done at lower temperatures, and therefore with increased equipment; recent practice being to arrange the dryers in series.

We have prepared a table showing the approximate costs of plants of different capacities with certain costs as a basis:

ESTIMATED COSTS OF PULVERIZED COAL PLANTS

Daily Capacity in net tons per 24 hours.	No. of Mills required.	Total cost.	Building only.
20	1-33″	$ 34,000.00	$ 5,500.00
50	1-42″	40,700.00	7,500.00
100	3-33″	49,500.00	10,700.00
200	3-42″	66 000.00	12,500.00
300	2-57″	79,200.00	14,750.00
400	3-57″	92,500.00	15,300.00
500	4-57″	106,700.00	16,000.00
750	5-57″	143,000.00	19,000.00
1000	7-57″	177,000.00	21,750.00

These costs are for complete plants, but there should be added 10% for engineering. They are for January, 1919. The estimates are for construction in the eastern or middle regions of the United States. We also include the distribution of an estimate for a plant of 500 tons per day.

COAL PLANT, CAPACITY 500 NET TONS PER DAY, 336 TONS CAPACITY IN 16 HOURS—ELECTRICALLY DRIVEN

BUILDING 32′ x 120′ erected:		
Structural steel	$10,200.00	
Corrugated roofing	782.00	
Corrugated siding	1,400.00	
Louvres	648.00	
Steel windows and doors	1,650.00	
Concrete foundations	1,200.00	
Excavations	200.00	
		$16,080.00
MACHINERY:		
Steel track, hoppers, grating, plate feeder, etc.	1,000.00	
Single roll coal crusher	1,410.00	
Motor for coal crusher	683.00	
Steel cased elevators	4,266.00	
Motor drives for elevators	1,720.00	
Magnetic separator	708.00	
Storage bins and supports	2,600.00	
Cradle feeder with driving mechanism	750.00	
Rotary coal dryer with exhauster, dust collector, piping and motor drive	12,670.00	
Brick work for dryer	1,400,00	
Pulverized coal equipment for dryer	1,500.00	
Screw conveyor with trough	700.00	
3 20-ton bins above mills, with discharge spouts, bin gates and spouts	4,571.00	
3 57″-mills with pulley drives, motors and belts	31,260.00	
Steel platforms, runways and stairs	4,000.00	
Discharge spouts from mills	300.00	
10-ton crane	1,500.00	
Screw conveyor with motor drive	620.00	
Conveyor cover, exhauster, dust collector and piping	1,900.00	
Wiring and installation of motors	4,000.00	
Machinery foundations and floors	3,150.00	
Excavations	1,000.00	
Miscellaneous erection, labour	3,750.00	
		85,458.00
Total		$101,538.00
Engineering 10%		10,150.00
		$111,688.00

General.—The experiments described give a general outline of the work done by Garred and Cavers, and the authors have presented general information obtained to date. The experiments of the Tennessee Copper Company are continuing with encouraging results, and at the plant of the International Nickel Company, the most recent work has been to endeavour to operate the furnace entirely without coke, following earlier work where an average of about 50% of the coke had been replaced. The results, with all coke eliminated, have not as yet been satisfactory, but are sufficiently encouraging to continue the experimentation with that object in view.

The processes involving the application of pulverized fuel to blast furnaces have been patented in the United States, Canada, and many foreign countries; the patentees, Garred and Cavers, both being engaged in work connected with the smelting of non-ferrous ores, and both were simultaneously working on practically the same problem, of the combustion of finely divided fuel in a blast furnace. Owing to the magnitude of the problems involved, a consolidation of their interests was effected recently, by the formation of the Garred-Cavers Corporation, New York, which company has acquired the patents issued and pending in connection with this work. It is expected that experiments on the smelting of silver-lead ores will be commenced in the near future, and we have every reason to believe the prospects are good for increasing the efficiency of blast furnace practice.

During the last few years, some twenty to thirty million tons of non-ferrous ores per year have been treated in blast furnaces in the United States, Canada, and Mexico, and it is believed that further developments of a satisfactory nature in connection with this work will enable a large proportion of these ores to be smelted with considerable economics in fuel.

DISCUSSION

MR. E. J. CARLYLE: I think possibly it might interest the Institute to know that Mr. Cavers, to whom Mr. Wotherspoon has referred and who, I suppose, has gone further than anyone

in applying pulverized fuel to blast furnaces, is a Canadian and a graduate of Queen's University. I had the pleasure of seeing his installation in Tennessee, and was much impressed by it.

It seems to me that, in order to burn efficiently, pulverized coal, like oil, must have a combustion chamber. It is immaterial whether that chamber is a masonry structure or an irregular channel through the charge of a blast furnace. There must be space in which ignition and combustion can take place. There may lie the crux of the whole matter. If the ore you are smelting is such that you have an open charge in the blast furnace, I think pulverized coal can be used to very great advantage. If, however, you have a large proportion of the furnace charge composed of fines, I am inclined to be sceptical.

Coal can be ground to the required fineness for 50 cents a ton or less, so that there is a very great economy in replacing coke with coal dust especially if the weight of coal dust substituted is actually less than that of the coke, as was the case in Mr. Cavers' work.

MR. BRADLEY STOUGHTON: It would be interesting to recall that it was due to the late David H. Browne at Copper Cliff that pulverized coal has been so successfully applied to the reverberatory furnace, and now apparently with equal success to the blast furnace. His memory means so much to us that I think we ought to mention this fact.

MR. WOTHERSPOON: It was through the late Dr. Browne that I myself became interested in this particular problem. I recall his words when he and Mr. Garred took me over the plant six months before his death. He said, "Wotherspoon, the greatest thing that has happened in recent years has just occurred. Come and look at it."

NOTES ON MOLYBDENUM AND THE PRODUCTION OF FERRO-MOLYBDENUM AT ORILLIA, ONT.

By B. C. Lamble

(Annual Meeting, Montreal, March, 1919)

The demand for molybdenum has greatly increased since 1914, especially in England and among our European Allies. This demand has been chiefly caused by the increased knowledge of its function in steel making. During the early stages of the war, it was ascertained that the metal of the German guns contained molybdenum in varying percentages. This undoubtedly was the reason for the British Government commandeering all supplies of the mineral molybdenite in the Empire.

Prior to 1914, three-quarters of the world's production was mined in Australia, the balance in Norway, Canada and the United States. Since that date the Canadian production has greatly increased. Valuable deposits have been found in Eastern Ontario and British Columbia, and probably the largest profitable low-grade body on this continent is that which was developed in 1916 at Quyon, Quebec, and which is now owned and operated under the name of the "Dominion Molybdenite Company, Limited."

Ores.—Molybdenum does not occur in the native state. The principal source of supply is molybdenite, the disulphide of molybdenum, MoS_2. It occurs in the form of plates, masses, scales, and grains. Its specific gravity is 4.7 to 4.8. It is very soft, about 1 to 1.5 on Mohs' scale, *i.e.*, can be easily scratched by the finger-nail. The lustre is metallic, the colour is lead grey, and the mineral has a greasy feel. In general appearance, molybdenite is very like graphite, but it is heavier, has a greenish-blue streak, and yields sulphur when heated on charcoal. Other ores are molybdite (molybdenum trioxide, MoO_3), which is a decomposition product of molybdenite; and wulfenite (molybdate of lead, $PbMoO_4$), which has not been found in commercial quantities in Canada.

Ore Concentration.—The supply of molybdenum ores being so limited, it is important to prevent losses, or reduce them to a

minimum. Up to within the last few years great difficulty was experienced in the concentration of molybdenum ores, but with the advent of the oil flotation process waste has been almost entirely eliminated, and a 95% extraction on a 1% ore is not unusual. At the same time a high-grade concentrate, carrying from 60 to 90% of molybdenite, is obtained. Canadian ores so far handled by the writer have been very clean—that is, they do not contain elements that would be harmful, such as tungsten, copper, arsenic, phosphorus, etc.

Metallurgy and Uses.—Pure molybdenum is a white metal; it is harder than silver, but will not scratch glass; it is easily filed and will take a high polish. The metal is malleable and may be welded. The melting point is exceedingly high, and has been determined, by the United States Bureau of Standards, as 2500°C., or 4500° F. This is more than 1400° C. above the melting point of copper; about 1000° C. higher than iron; and 745° C. higher than platinum. Osmium, tantalum, and tungsten, are the only three metals listed by the Bureau of Standards as having higher melting points. The specific gravity of ductile molybdenum is given as 10.02. Molybdenum, produced in the electric furnace by the reduction of molybdic oxide with carbon, does not possess the same physical properties as pure molybdenum, owing to its absorption of carbon. Metal obtained by this method is grey and brittle. It is also very hard and scratches steel and quartz; even the hardest file will not cut it when it contains a certain proportion of carbon. The melting point of the grey metal is much below that of pure molybdenum, and its specific gravity is also lower, ranging from 8.6 to 8.9, depending on the amount of carbon present. Moissan states that when pure molybdenum is surrounded with carbon, and heated to 1500° C., it absorbs carbon, and becomes hard. Inversely, if carbon-bearing molybdenum is melted with molybdenum dioxide, the carbon in the metal is oxidized and the molybdenum is refined. Metall c molybdenum is only slowly oxidized at ordinary temperatures, and drawn molybdenum wire retains its lustre almost indefinitely. On prolonged heating at a dull red heat the metal becomes covered with a white coating

of molybdic trioxide, and at 600° C. it oxidizes rapidly and the trioxide sublimes. The metal is readily soluble in nitric, and in hot concentrated sulphuric acid, as well as in *aqua regia*. It is not attacked by hydrofluoric acid or by dilute sulphuric or hydrochloric acids. In its resistance to common acids it differs materially from iron. Some of its alloys also have remarkable acid-resisting properties, and for this reason have special uses. When reduced in wind and electric furnaces molybdenum forms compounds with carbon silicon, etc. Molybdenum forms alloys with iron and other metals, and in many instances has the property of imparting strength, toughness, and hardness in a remarkable degree. The conversion of molybdenite (MoS_2) into the trioxide (MoO_3) is a difficult operation. It is effected either by a volatilizing roast, or by fusion with sodium nitrate and further treatment with oxide. In order to prepare pure molybdenum metal, the pure trioxide, or one of the chlorides in a pure state, is heated to redness in a current of hydrogen. The electric furnace has largely replaced other methods of reduction, and produces the molybdenum metal, or ferro-molybdenum alloys, from roasted ore, or in some cases directly from the sulphide, which method is described later. Metallic molybdenum is also prepared by the alumino-thermic process, similar to the well known 'Thermit' reaction; a mixture of molybdic acid and metallic aluminium, both in powdered form, is used.

The principal use of molybdenum is in the manufacture of alloy steels, to which it imparts many desirable properties. These steels are used for a large variety of purposes, such as for crank-shaft and propeller shaft forgings, high pressure boiler plate, guns of large bore, rifle barrels, armour plate, armour-piercing projectiles, permanent magnets, wire, and for self-hardening and high-speed machine tools. Metallic molybdenum is used in various electrical contact making and breaking devices, in X-ray tubes, and in voltage rectifiers; in the form of wire filament supports in incandescent electric lamps, and also for winding electric resistance furnaces, and in dentistry.

Regarding the manufacture of molybdenum chemicals, such as molybdic acid and ammonium molybdate crystals, I

believe that we are the only producers of these pure chemicals in Canada. We have just completed a plant for the manufacture of at least 2,000 pounds of these chemicals per month; practically all of this product will go to the United States, where several tons annually are used for the determination of phosphorus in iron and steel analyses. The Canadian market only calls for about three tons per year, all of which we hope to supply.

As to the production of pure molybdenum in Canada, we started some research work at Orillia, and it is hoped that the investigations will be continued by the Federal Department of Mines. As regards the production of ferro alloys in Canada, there is no reason why an export business of considerable size could not be built up, especially with the following alloys—molybdenum, chrome, nickel, cobalt, silicon, and manganese; for we have all the requisite natural resources, *viz.*, ores, water-powers for electrical energy, brains, and brawn.

The Production of Ferro-Molybdenum at Orillia.—In the early part of 1915, experimentation on the concentration of molybdenite ores by straight water flotation was started at Orillia. These experiments were fairly successful, and a concentrator was erected at Renfrew, Ontario, the concentrate produced being sent to Orillia for treatment. The mining prospects from which the ore came were situated in the county of Renfrew, and the ore proved to be of too low a grade for profitable work. Both the mining and concentrating were therefore abandoned, and the supply of raw material was obtained in the open market.

Up to the beginning of 1916 we converted all the molybdenite produced into molybdic acid and ammonium molybdate, which were sold to United States consumers. In February, 1916, experimental work was begun on the production of ferro-molybdenum from molybdenite in the electric furnace. The first furnace was crude, but some very useful results were obtained. At first the molybdenite concentrates were given an oxidizing roast at a low temperature in an oil-fired furnace, thereby converting the greater part of the molybdenite into the oxides of molybdenum. These crude oxides were then leached out

with strong ammonia water, giving an ammonium molybdate solution, which was filtered. The solution was then heated in a large steam-jacketed vessel until practically all of the ammonia had been driven off, leaving a crude molybdic acid, or oxide. This acid was then reduced with petroleum coke in the furnace, steel scrap turnings being added for the iron addition. We did not at first attempt to tap the metal from the furnace, but kept on adding charges until 500 pounds of metal had been accumulated. The furnace was then allowed to cool, the crucible broken, and the salamander of metal taken out.

This furnace did not prove satisfactory, so one of better design was constructed as follows: A cast iron bottom was made, 54 in. in diameter, 4 in. thick, and saucer shaped. A wrought iron shell 52 in. in diameter, $\frac{3}{8}$ in. thick, and 3 ft. high, with a space cut out for a tap hole, was fitted over the cast iron bottom. The saucer of the bottom was packed with carbon paste, giving an even surface. A block of amorphous carbon 28 by 28 by 9 in. was then set on the carbon paste. On this block a crucible of pieces of 4-in. solid square carbon was built, so that the final dimensions of the carbon crucible were 20 by 20 by 20 in. A tap hole about 1 in. square was cut in the front piece of carbon. Around this carbon crucible were placed magnesite bricks, 9 by 4 in. straights, leaving space enough for the tap hole. The rest of the space between the magnesite bricks and the shell of the furnace was filled in with ordinary fire-brick and ground coke. At the tap hole a piece of graphitic carbon was fitted from the bottom of the crucible to the outside of the shell. This piece of carbon had a decided slope, so that the metal and slag would run quickly.

A 10-in. graphite carbon electrode was suspended through the centre of the furnace and held by a water-cooled head. This was suspended by a $\frac{1}{2}$-in. wire cable running through small sheaves attached to a mast constructed from 4-in. pipe; the cable was continued to a small winch controlled by a 1-H.P. direct-current shunt wound motor. The power was supplied from the town lines at 2,200 volts, and transformed, by means of four 50-K.W. transformers, to 55 volts on the secondary side.

The current was carried to the furnace through two sets of heavy copper cables, one set being strongly bolted to the cast iron bottom of the furnace, and the other to the electrode head. The mouth of the tap hole was blocked with carbon paste and the rest of the space filled with fine coke, and then finished with fire-clay. The charges consisted of about 200 lb. in weight, but they were not placed in the furnace until an arc had been formed between the bottom of the crucible and the electrode. During the running of the furnace the power consumption showed the furnace to be taking 235 H.P., equivalent to 175 kilowatts, the voltage being maintained at 55, and the amperage between 4,000 and 4,500.

The reduction of the molybdic acid was based on the equation $MoO_3+3C=Mo+3CO$. Several hundred pounds of ferro-molybdenum were made in this way, which fulfilled the following specification: molybdenum 70%, carbon 4%, sulphur 0.4%, phosphorus 0.4%.

The costs of this method of production were thought to be too high, because of the preliminary treatment of the concentrates and the losses of molybdenum due to dusting and volatilization; these were found to be about 20% of the molybdenum contained. It was suggested by one of the investigators that a trial run be made by reducing the green molybdenite concentrates directly without roasting them. The following charge was therefore made up: 500 lb. of concentrates (assaying 65% MoS_2, 30% FeS_2, and 5% SiO_2, and giving theoretically over a 70% alloy) were mixed with lime and coke according to the equation $2MoS_2+2CaO+3C=2Mo+2CaS+2CO+CS_2$. Pure molybdenite contains 60% of molybdenum, and 40% of sulphur. According to the above reaction, 100 parts of molybdenum are reduced from 170 parts of molybdenite by 18.8 parts of carbon. For every 100 parts of molybdenum, 58 parts of lime are necessary for slagging the sulphur as calcium sulphide. Extra lime must be added to take care of the sulphur in the iron pyrites, and of the silica. We found this method of fluxing to be very satisfactory, and we experienced no difficulty in tapping metal that met the Imperial Munition Board's specifi-

cation. A second furnace was installed, and we produced about 100 tons of ferro-molybdenum averaging 71% molybdenum, 3.66% carbon, 0.08% sulphur, 0.03% phosphorus, 23.8% iron, 1.35% silicon, copper trace, arsenic and tungsten nil. By this method the actual extraction has averaged, in the first treatment, 80% of the molybdenum fed to the furnace. There is very little loss by volatilization. The chief losses occur by (1) dusting (*i.e.*, fine particles of molybdenite carried off with lime and coke) and (2) slagging (*i.e.*, metal mechanically held in the slag). The losses in these respects are, by dusting 11%, by slagging 7%. The dusting loss has been overcome somewhat by the installation of a dust-collecting outfit set up over the furnaces. Ninety per cent of the metal held in the slag can be recovered by table concentration, some experiments having been made that give a concentrate carrying over 50% molybdenum.

The furnace described is known as a 'single-phase,' or 'one-electrode,' type. It is our intention to install a 'two-phase' furnace with a roof, which it is anticipated will give a better extraction and a lower cost of production.

The actual power consumption has been from 6 to 7 kilowatt hours per pound of molybdenum produced.

RECENT IMPROVEMENTS IN THE CONCENTRATION OF MOLYBDENITE

By H. H. Claudet

(Annual Meeting, Montreal, March, 1919)

Oil flotation has for many years been proved to be an efficient method of concentrating molybdenite ores although this has not been generally recognized, and consequently its application has been limited until a comparatively recent date. Since 1913, the Elmore Vacuum Process has been successfully applied to treat low grade molybdenite ores in Norway, as the result of experiments prior to 1913, which led to these installations.

It might be of historical interest to quote here tests made in Messrs. Elmore's laboratories probably as far back as 1905-06, thirteen years ago, the tabulated results of which, given below, indicate the amentability of oil flotation to these ores:

	Molbydenite ore. Quartz Gangue.	Molbydenite ore. Gangue Quartz, Slate, Mica and Magnetite.	Molybdenite ore
Ore	5.21 Mo	2.61 Mo	3.07 Mo
Tailings	0.17	0.10	0.06 (0.1 MoS_2)
Concentrates	54.70 (91.16MoS_2)	47.20 (78.66MoS_2)	51.57 (85.95MoS_2)
Recovery, %	97	96.2	98.1

Upon consideration of the above results, it may be wondered why oil flotation was not more generally applied sooner, and why reference has so often been made to the extreme difficulty of concentrating molybdenite. Probably this was due more to the uncertainty in the mining and marketing of molybdenite than to anything else, and it is more than likely that without the effect of the war as a stimulant for the production of molybdenum little progress would have been made and many of the molybdenite properties which have been exploited and on which concentrating mills have been installed, would have remained inactive. Prior to the war, the chief difficulty was to find deposits high enough in grade and promising a sufficient quantity of ore to warrant their operation and to find assurance for the

operator that the market would be satisfactory. With these uncertainties, it was natural that until recent years there was not a great deal of interest shown in the production of molybdenite, and in regard to its concentration, the satisfactory results attained by oil flotation in Norway were either unknown or ignored. Consequently when suddenly the demand came, a variety of systems of concentration involving in some cases untried ideas, were exploited, all of which are now giving place to oil flotation.

This statement by no means implies that these different systems were all failures, for, in the case of the work done at the Dominion Government ore testing plant at Ottawa using the Wood film flotation machines and modifications, good results were obtained and molybdenite was produced there at a time when it was much needed. But on the whole, it can be said that if more energy had been expended in trying to perfect and develope the systems commercially established years ago, instead of experimenting along new lines, a saving in concentration plant expenditure would have been achieved.

Any account of molybdenite concentration in Canada would be incomplete without reference to the work of Henry E. Wood, and his application of Wood film flotation machines for the treatment of Canadian molybdenite which contributed substantially to the production in Canada during 1915-16. Ultimately the more delicate operation of film flotation was replaced by oil flotation.

RECENT DEVELOPMENTS

It is not the author's intention to discuss the comparative merits of the different systems of oil flotation; but rather to endeavor to make passing reference to the main developments observed.

As already mentioned, it was demonstrated years ago that satisfactory commercial results could be obtained on low grade molybdenite ores by the Elmore system, which in a simple plant with one machine and one operation made marketable concen-

trates and a satisfactory recovery. This method was extensively applied in Norway with success.

But a decided advance in the concentration of molybdenite came in 1917 when experimental work was carried out on Canadian molybdenite ores in the laboratories of the General Engineering Company using the Callow pneumatic flotation machine. These experiments led to the application of a highly efficient adjunct to the flotation system permitting a further separation or cleaning of the flotation concentrates. The cleaning of the concentrates is accomplished by passing them over a fairly fine mesh screen upon which the bulk of the molybdenite remains, owing to its property, when oiled, of becoming flocculent, even though the grains forming the flocks or agglomerations may be fine enough to pass through the sieve. On the other hand, gangue slime and fine pyrites that may have floated over with the molybdenite remain in a granular state and pass through the sieve, thereby effecting a most efficient separation. The application of this principle was worked out by E. B. Thornhill and is protected by a patent application owned by the General Engineering Company.

This experimental work led to a commercial installation to treat the Dominion Molybdenite Company's ore at Quyon, Que. The plant was designed by the General Engineering Company's staff of engineers and under the careful and efficient supervision of the management of the Dominion Molybdenite Co. the mill has been brought to, and maintained at, a remarkable state of efficiency both as regards the recovery and the grade of molybdenite produced, the actual recovery ranging from 92% to 98½% and the grade of concentrates averaging over 90% MoS_2. A flotation plant of this type consists of Callow rougher-cells, Callow cleaner-cells, Callow travelling belt 80-mesh screen, a dewatering drag, and a dryer for the concentrates.

A ball mill is used for grinding the ore to the desired fineness; it operates in closed circuit with a classifier of the Dorr type so that the material which is too coarse for treatment is returned

to the ball mill for further grinding, the classifier overflow being fed to the rougher-cells.

The concentrates made in the rougher-cell are subsequently cleaned in the cleaner-cells; therefore their grade is not important so long as the tailings leaving the rougher-cells—and going to waste—are free from molybdenite. This arrangement permits of making clean tailings.

The concentrates floated in the cleaner-cell are adjusted to come over as clean as possible, a water spray being used to break down the froth. This causes high tailings in the cleaner cells, but as this remains in the circuit, by being returned to the rougher-cells for retreatment, its content is immaterial.

The cleaner-cell concentrates are sent to an 80-mesh Callow screen, the material remaining on the screen being the finished product which is sent to a dryer and afterwards packed in cans for shipment, while the material passing through the screen remains in the circuit and is returned to the rougher-cells for retreatment.

In the whole operation there are only two outlets for products, namely the finished concentrates and the rougher-cell tailings which go to waste. All the other mill products remain in the circuit until they decide whether they will remain with the concentrates or tailings. It is very interesting to note that the pyrite and slime do not build up in the circuit, as one would imagine, but apparently after two or three trips with the concentrates these products join the rest of the worthless gangue. Further, any fine molybdenite which finds its way through the screen subsequently becomes attached to the bulk of the flocculated molybdenite, ultimately going over as concentrates.

This system is described in detail, as I believe it indicates progress in the treatment of molybdenite, and is the most efficient system I know.

Naturally, some ores are more amenable than others, and while there are certain ores which are difficult to float and perhaps might not lend themselves to the above treatment, my

own experience has been that the majority are suited to oil flotation, and in almost all cases the use of the screen would increase the efficiency of the plant considerably.

Oxidized ores are difficult to float, and as far as I know molybdic oxide has not been floated and films of it on the molybdenite hinder flotation.

Chalcopyrite is troublesome, as it has a greater tendency than other minerals to float with the molybdenite.

Iron pyrites and pyrrhotite are separated from the molybdenite by direct preferential flotation and more completely by the action of the screen as described above, as most of the iron sulphides which float over with the molybdenite will pass through the screen.

Mica usually gives no trouble, as by proper adjustment it does not float; but very low grade ores with heavy iron and mica contents are not desirable, and with ores of this type it is usually out of the question to make high grade concentrates. The same can be said of extremely finely disseminated ores which usually will not give concentrates much over 60% MoS_2.

The separation effected by the screen, however, is even more pronounced in these cases, and the return circuit, which builds up the molybdenite contents of the feed to the rougher-cells, adds to the success attained with these types of low grade ores.

Below are given some figures taken from laboratory tests made on different molybdenite ores to illustrate the work of the screen when treating refractory ores:

Low Grade Colorado Ore, Heavy Pyrite and Pyrrhotite Containing 0.13% MoS_2.

Flotation Concentrates:	By Wt.	Assy. MoS_2	Total % of contents.
Before screening	4.08%	3.02%	96.3%
Remaining on 80 mesh screen. Finished product	0.15%	65.5%	76.7%
Passing through screen. Re-treatment product	3.93%	0.64%	19.6%

Low Grade Canadian Ore, Containing 0.30% MoS_2

Flotation Concentrates:	By Wt.	Assy. MoS_2	Total % of contents.
Before screening..	2.0%	12.0%	80.4%
Remaining on 80 mesh screen. Finished product.....	0.3%	76.7%	77.0%
Passing through screen. Re-treatment product.....	1.7%	0.6%	3.4%

Molybdenite Tailings, Canada, Containing 0.63% MoS_2

Flotation Concentrates:	By Wt.	Assy. MoS_2	Total % of contents.
Before screening.....	4.66%	11.9%	87.2%
Remaining on 80 mesh screen. Finished product.....	0.61%	71.0%	68.0%
Passing through screen. Re-treatment product.....	4.05%	3.0%	19.2%

Colorado Ore, Containing 0.74% MoS_2

Flotation Concentrates:	By Wt.	Assy. MoS_2	Total % of contents.
Before screening.....	8.05%	8.5%	92.28%
Remaining on 80 mesh screen. Finished product.....	0.85%	72.1%	82.58%
Passing through screen. Re-treatment product.....	7.20%	1.0%	9.70%

It will be noted that clean tailings are obtained by making low grade flotation concentrates varying in the above four cases from 3% to 12% MoS_2 and that merely by screening it, a finished concentrate is obtained, containing 65% to 77% MoS_2.

It should be explained here that the grade of flotation concentrates in these four cases is unusually low, due to the ores being difficult to treat, but the figures are given to illustrate the efficiency of the screen. In ordinary practice the flotation concentrates would contain about 70% MoS_2 and this would be enriched by the screen to over 90% MoS_2.

CONCLUSION AND PROSPECTS

The present production of molybdenum in Canada has not reached the mark anticipated two years ago, but each year has shown a steady increase. Since 1914, 431 tons of MoS_2 have

been produced, valued at $962,835, or approximately $1.11 per pound.

The industry needs stabilizing, and if several Canadian mines can be brought to the stage of continuous production, a steady demand for all their output should be secured at a profitable figure, although war prices cannot be expected.

War needs have developed numerous uses for molybdenum, the application of which may lead to a demand for molybdenum in times of peace which will more or less take the place of the demand during the war, and it is reasonable to expect that in this expansion of its utility a fair price will be maintained, at any rate considerably higher than pre-war prices.

Below are tabulated figures, giving the production in Canada for the years 1914 to 1918 inclusive. These are furnished by the courtesy of the Division of Mineral Resources and Statistics:

MOLYBDENITE PRODUCTION IN CANADA

	Ore Treated, Tons.	Ore & Concs. Tons Shipped.	Contents of Shipments. Pounds MoS_2.	Value $
1914	—	16.5	3,814	2,063
1915	—	216.	29,210	28,450
1916	9,106	6,539.	156.461	188,316
1917	22,605	1,554.3	288,705	320.006
1918	33,700	208.	384,000	424,000
			862,190	$962,835

DISCUSSION.

MR. G. C. MACKENZIE; There is one point which has not been touched upon by the author of this paper, and that is the treatment of an oxidized ore containing iron sulphate in solution. The Department of Mines found that these ores were difficult to work, as the iron sulphate generally killed the froth effectively. This is one of the reasons why the Department of Mines used the Wood system so long; and even when we were

thoroughly convinced of the value of the Callow machine we retained the Wood machines as we found them very valuable in treating various lots of oxidized ores. There has been some criticism directed at the Department for not adopting the frothing system of flotation earlier, but our reasons for not doing so were based on actual experience in the treatment of very many different ores. I might also say that molybdenite ores containing copper are generally worked to more advantage by the Wood machine than by any frothing machine.

MR. H. H. CLAUDET: Of course we do not claim to treat every ore. No doubt, some molybdenite ores will be found from time to time that are difficult to treat by oil flotation, or even may not respond to its treatment at all, in which case other processes or modifications that are found to give better results can be applied. I can only speak from personal experience gained both here and in Norway, which indicate that with the majority of molybdenite ores so far encountered, oil flotation is by far the most efficient system of concentration. I have no doubt, as Mr. Mackenzie says, certain oxidized ores containing soluble salts are difficult to treat in an oil flotation plant, and in these instances the Wood flotation machines could be employed.

NODULIZING COPPER CONCENTRATE

By Oscar Lachmund

(Western Branch, Nelson Meeting, June, 1919)

The preparation of copper concentrate for the market, especially the product derived from the flotation process, is a problem that confronts the British Columbian producer to-day, assuming that it is the intention, ultimately, to smelt all domestic copper ores within the province.

At present, the only outlet for such material is with a foreign reverberatory plant, there being no such furnaces in the province. This means excessive railway freight charges, on account of the high moisture content of the concentrate, or an appreciable loss of fines in transit, if the product is dried before shipping, to say nothing of the additional cost of drying.

There being several blast furnace plants in British Columbia, the logical thing to do, is to put the concentrate in proper physical condition for blast furnace practice.

Three methods suggest themselves—briquetting, sintering and nodulizing. The first is not very satisfactory, as briquettes do not lend themselves to railway transportation, even when made with a suitable binding mixture, as the loss of fines, by abrasion in handling the briquettes, is large. Sintering, or agglomerating the sulphides in roasting pans or pots, makes an undesirable product for blast furnace practice in British Columbia, as far as retaining the sulphur is concerned, as it brings the percentage down as low as 5.

Nodulizing, that is, getting the fines into round particles, or nodules, by passing the material through a revolving cylindrical furnace, or kiln, under application of heat, has been successfully carried out at several large plants. At Chrome, New Jersey, the United States Metals Refining Company worked up a large accumulation of flue dust, and later tried it on flotation concentrate. In Chile, the Braden Copper Company is treating its copper concentrate, including flotation product, by means of rotary kilns.

The late James H. Payne first conceived the idea of applying the 'clinkering' operation in cement manufacture, to the treatment of fine ores, flue dust, and copper sulphide concentrate. After numerous laboratory experiments, which indicated that the process would be practicable on a commercial scale, he introduced it at the plant of the United States Metals Refining Co., where the work was carried on under the supervision of Mr. Lawrence Addicks, the manager. Mr. Addicks has described the operation in an article published in the bulletin of the American Institute of Mining and Metallurgical Engineers, No. 91, pp. 1671-1674. Subsequent progress was detailed in a discussion presented by Mr. Payne and Mr. R. M. Draper, the smelter superintendent at Chrome. This will be found on pp. 2718-2720 of a later issue of the bulletin.

These men being the pioneers in the operation of the nodulizing process, the writer has drawn largely from their contributions on the subject for material for this paper.

On account of the small size of the material treated, one would imagine that a considerable loss of fines, from dusting, would be experienced, but Mr. Payne states that "the flue dust produced by the kiln itself is practically *nil*, although some of the material treated has been as fine as 82 per cent through 100 mesh. The material is fed wet and any dust present precipitates in the atmosphere of steam at the exit end. The material, furthermore, is constantly moving downward to the hot end, and is in a dry, dusty state but a short time, soon changing to a moist condition, which is no longer dust."

Mr. Addicks, referring to the same subject, says: "No trouble was experienced from flue dust blowing out of the kiln. In dry process cement work, where 95 per cent of the material fed will pass a 100-mesh screen, only 3 per cent flue dust is made. In the case of our flue dust, about 25 per cent would pass 100 mesh."

Regarding the size of the product made, it would seem that under perfect working conditions, there would be no material fine enough to be blown out of the blast furnace. Mr. Payne states that an umber of samples tested showed from 42 to 45 per cent of voids.

The retention in the nodules of a maximum portion of the sulphur of the original charge is the attractive feature of the process to the blast furnace operator. Mr. Payne is very positive in his claims along these lines. He goes on to say: "The action of the furnace is independent of the sulphur content. . . The amount of sulphur in the nodules is under perfect control. It can be as high as 15 per cent or as low as 5 per cent, as may be desired. The upper limit for good working seems to be about 15 per cent, as the nodules are very sticky with a higher sulphur content. A product running 13 per cent to 15 per cent sulphur has been readily obtained on all oil floated concentrates so far tried, where the object was to retain all the sulphur possible. This makes pyritic blast furnace smelting of sulphide concentrates possible."

Mr. R. M. Draper, who superintended operations at the Chrome plant, says:—"Our consumption of oil was about 6 to 7 gals. per ton of concentrates. The nodules were very satisfactory from a blast furnace point of view when charged into the furnace cold, although we had considerable trouble with crusts if we put in too many of the hot nodules, due probably to the fact that they were near the melting point when fed into the furnace and naturally melted much higher up in the charge. I think we would have had this difficulty with any material that was charged hot. In fact, we found the same tendency for cursts to be formed when we tried the experiment of charging hot converter slag into the furnace several years ago."

From the above it appears that nodulizing the fine ores, flue dust and sulphide concentrate is the solution of the problem of preparing this material for the market, where reverberatory furnaces are not available. In fact, under average conditions, smelting the nodules in the blast furnace could be done more cheaply.

The writer was called upon recently to supervise a series of experiments along these lines, the concentrate to be tested having been produced in British Columbia. For the preliminary work a sheet iron tube, 12 in. in diameter by about 10 ft. in length, was used. This was not lined with fire brick

or other refractory material, as only small lots of concentrate were tried at a time, and each test was of short duration. The results indicated that a certain amount of desirable product could be made in this way; but the apparatus was too small and too crude, and the fuel control too uncertain, to carry on for any length of time. No tests were made as to sulphur elimination, the main object being to ascertain whether nodules could be made. This having been determined satisfactorily, we next tried the process on a large scale. It was decided to use the plant of an idle cement works, which contained, among other things, a cylindrical, revolving furnace, 125 ft. long by 7 ft. in diameter (inside the fire brick lining), and a coal crushing plant, the fuel used being pulverised coal.

Never having seen any account of the use of pulverised coal for nodulizing copper sulphide concentrate, we were rather timid about trying it, but oil fuel could not be used as the plant was not arranged for burning it. The former superintendent of the cement works was secured, and as he was familiar with pulverised coal firing, we commenced operations, after procuring the services of Mr. Draper, who conducted the experiments personally.

Almost the first thing we discovered was that it required a much lower temperature for making nodules from the concentrate, than it did in the dry process cement practice of calcining clinker. The burner was too large and the feed difficult to control, the result being that we produced everything from fine, roasted dust to lumps of partially smelted material as large as a man's fist. When conditions were right, some very good nodules were made. This shows that pulverised coal can be used successfully as fuel, provided the proper equipment is employed. Pulverised coal fuel is being used to-day at reverberatory smelting works, also under boilers of various types, and the feed is under perfect control. A similar arrangement, no doubt, could be devised for the nodulizing kiln.

We had about the same experience with the sulphur as Mr. Payne described in his paper, that is, we eliminated nearly all of the sulphur in some cases, while in others we kept the loss

down to about 30 per cent. In Mr. Draper's opinion the nodulizing of sulphide concentrate can be done as successfully with pulverised coal fuel as with oil; also, the sulphur retention is under better control when using pulverised coal.

In the matter of costs, as it was impossible to obtain favourable working conditions at all times, the total expense of carrying on these tests cannot be charged against the operation. Attempts were made to get representative cost figures when the kiln was doing good work, but these are more or less estimates. Close account was kept of the amount of coal used. Between 12 and 14 tons of concentrate were treated with one ton of coal. Figuring the coal at $5.00 per ton, pulverised and in the bin, the cost per ton of concentrate nodulized should not exceed 50c, to which must be added overhead and other expenses, say, 50c, making a total of $1.00 per ton. This might be a trifle higher under present disturbed conditions.

The capacity of a kiln 125 ft. long, such as was used in these experiments, should be about 100 tons of concentrate per 24 hours. The furnace at Chrome, according to Mr. Addicks, was 60 ft. by 6 ft., and handled about 75 tons of material per day.

The use of pulverised coal fuel is rapidly gaining favour. The complete combustion of the coal dust raises the fuel value and permits of the use of inferior grades of coal. This fact should make of commercial value certain deposits of so-called 'semi-lignite' coals in western British Columbia, which are at present without a market.

It is most likely that any future discoveries of large copper deposits in this province will be of the 'disseminated' type, or, at any rate, of so low a grade as to call for wet concentration. The resulting concentrate, whether produced in jigs, on tables, or with flotation machines, will have to be shipped some distance to a smelter. What could be more ideal than to drive off all the moisture from one's product, and as much sulphur as was undesirable, thereby saving money on freight charges and at the same time delivering to the blast furnace smelters a most attractive product.

THE COMMERCIAL FEASIBILITY OF THE ELECTRIC SMELTING OF IRON ORES IN BRITISH COLUMBIA.

By Alfred Stansfield

In the summer of 1918, I was asked by the Minister of Mines of British Columbia to investigate and report to him on the commercial possibility of smelting electrically the magnetite iron ores of that province for the production of pig iron.

The object of the investigation was no doubt the production of pig iron for use in foundries, and also the production of steel for shipbuilding and other purposes, but I was instructed to devote my attention in the first instance to the production of pig iron.

The first thing to consider was the amount and character of the market available in British Columbia, as it did not seem likely that we could count on any considerable export of a high priced product such as electric pig iron. Investigations in Vancouver showed that it would not be safe to count on a consumption of more than 20 or 25 tons of pig iron daily in the foundries of the province. It was also found that the electric pig iron produced would have to be sold as ordinary foundry iron and could not command any higher price on account of its special qualities or purity.

In this connection it may be mentioned that in Sweden, where the electric smelting of iron ores has been commercially established, the industry depends on the fact that the pig iron produced in the electric furnace can command, on account of its special quality, a higher price than pig iron made in the ordinary way in the blast furnace. In British Columbia this was not possible, and the electric smelting of pig iron, which is necessarily more costly than smelting in the blast furnace, could only be feasible in view of the high price that must be paid for any kind of pig iron in that province. This condition of high prices will obviously only continue until such time as the ordinary smelting of iron ores in the blast furnace is begun at some point on the Pacific coast.

In view of the very limited size of the market for pig iron, it was necessary to consider other means of disposing of the product, and it seemed reasonable to assume that an equal quantity of iron could be converted into steel and sold in that form. There was, therefore, the possibility of producing some 45 or 50 tons of pig iron, daily, by the electric smelting of iron ores.

The next point to take up was the supply of iron ore, and information in this connection was provided by Mr. Fleet Robertson and Mr. W. Brewer. The latter prepared an elaborate table of the available iron ore deposits in British Columbia. The information obtained showed a number of deposits of magnetite mostly of fair quality; but these deposits have not been sufficiently developed for it to be safe to count on a very large supply at any point. There was, however, a sufficient supply of ore for the somewhat moderate requirements of an electric smelting plant. Mr. Brewer estimated that a supply of iron ore could be obtained containing from 50 to 55 per cent of iron. The ore would be practically free from phosphorus and titanium, and the sulphur could be kept as low as 0.1 per cent. The ore would also be practically free from copper. It was estimated that a supply of 50,000 tons per annum of this grade of ore, could be delivered at a suitable site for smelting at a cost of about $4.00 per net ton, which would include a small royalty to the owner of the mine.

The electric smelting of iron ores has been developed to the greatest extent in Sweden by the Electro-Metals Company of that country. Other attempts to smelt iron ores have been made in California and elsewhere, but they have not attained to commercial success. It seems, therefore, that the Swedish type of furnace should be adopted in a new undertaking for the production of electric pig iron.

The electric smelting of iron ores requires a supply of carbonaceous material for the reduction of the ore, and for this purpose charcoal can be made economically from the wood-waste produced by the sawmills in the neighbourhood of

Vancouver. Experiments would have to be carried out, however, to find the best type of kiln to use for the charring of this waste economically.

The cost of smelting the British Columbia iron ores in a furnace of the Swedish type is indicated in the following table; it being understood that the plant produces daily about 50 tons of pig iron and also contains electrical furnaces for the daily production of 50 tons of steel and a few tons of ferro-alloys. The figures given for electric power and other supplies are sufficient to allow for a reasonable irregularity of use on account of repairs and for other reasons. The table includes also an item for interest and depreciation and a payment for royalty to the Electro-Metals Company.

COST OF ELECTRIC SMELTING

(Smelting in Swedish Furnace with $15 Power)

Iron ore, 2 net tons at $4	$ 8.00
Electric power, 0.45 horse-power year at $15	6.75
Charcoal, 0.4 net tons at $8	3.20
Electrodes, 15 lb. at 8 cents	1.20
Repairs and maintenance	1.00
Labour	4.50
Management	2.00
Interest, 6 per cent on total capital, and depreciation, 10 per cent on cost of plant	2.60
Royalty to Electro-Metals Company	.50
Total	$29.75

The electric smelting of iron ores, although very simple, is in a sense a crude application of electric power, an unduly large amount of power being required for the reduction of the ore to the metallic state, and even in the best type of furnace the charcoal and electric energy are somewhat wastefully employed.

At the time of my investigation the war was still in progress, and in view of this, it was important to establish a plant

for the production of iron at the earliest possible time. I directed my attention, therefore, to the utilization of existing electrical powers for this purpose. The investigation indicated that the production of electrical pig iron on a large scale could probably be carried out economically by the development of a new hydro-electric power and the establishment of a large plant containing the Swedish type of electric furnace. At the time of my report, however, the immediate development of a new water-power was out of the question, and the only possibility was the employment of existing electric powers for the production of iron on a small scale.

Under these conditions, as the plant was necessarily temporary and would have to be moved at an early date, it seemed better to employ a simpler type of furnace such as that used in the production of ferro-alloys, even although the economy obtained would be somewhat less than with the use of the more elaborate Swedish furnace. This procedure was also recommended because it seemed probable that the furnaces would be used ultimately for the production of ferro-alloys, and that a new plant on a larger scale would be built as soon as suitable water-power had been developed for its supply.

British Columbia is well provided with water-powers, and many of these can be developed cheaply for electric smelting and similar industries. I was informed that some of these water-powers could be developed so cheaply as to yield an electric horse-power for electric smelting at a cost of $10.00 per year. On the other hand, the electric power available at the time of my report could not be obtained at less than 0.5 cents per kilowatt hour, which would correspond, in view of the nature of its use, to about $28 per horse-power-year. At that high price the electric smelting of pig iron was out of the question, although, as has already been stated, the information obtained appears to show that with the development of a suitable water-power the British Columbia ores could be smelted in electric furnaces at a price that would permit of operation at a profit.

Many attempts have been made in recent years to improve on this practice. The general idea underlying these attempts is

that of the reduction of the ore at moderate temperatures by the aid of fuel heat, and by means either of charcoal or of reducing gases, leaving the electric furnace to melt the reduced metal. These methods are so revolutionary, and involve so many steps that are entirely new in practice, that it is impossible at present to speak certainly in regard to their success, but the economy which may be reached in this way is so important that it seems inadvisable to put up a large electric smelting plant of the existing type before we have satisfied ourselves of the commercjal possibility or otherwise of the new processes.

TITANIFEROUS IRON ORES IN CANADA

By W. L. Goodwin

(Annual Meeting, Montreal, March, 1919)

So far as known our country is not rich in the ordinary iron ores, and there is a growing conviction that our economic development requires the careful scientific utilization of such iron ore resources as we have. This is my reason for a review of a class of ore which has never been looked upon favorably by blast furnace men, although their objections when given critical examination do not appear to be altogether well founded. The presence of titanium in iron ores is so common that it may be considered to be almost universal, although some ores contain very small quantities of it. Its presence was not suspected in many cases where smelting operations were carried on for years without any trouble. A. J. Rossi reviewed the literature of the subject in 1890 (Journal Am. Ch. Society, 1890, p. 91). His paper shows that iron ores containing from 3% to 15% TiO_2 have been in common use in blast furnaces in Sweden, Norway, Russia, England, etc., and that even a higher percentage of titanic acid has given no difficulty in some cases. The literature of this subject is extensive. I have gone over a great deal of it, and am convinced that it will be worth our while to re-examine the situation in order to find out if there is any insurmountable difficulty in the way of utilizing our large and wide-spread deposits of this class of iron ore.

Titaniferous iron ores are found in Alberta, Ontario, and Quebec. The Alberta occurrence is an interesting one, i.e., that at Burmis claims, 9 miles east of Blairmore, where the ore occurs interstratified with soft sandstones. Probably the Ontario deposits are the most important, being found at intervals from the extreme west to the eastern end of the province. In the east a number of claims have been worked. In Leeds County, the Matthews mine (one mile from Newboro, on the Brockville Division of the C. N. R.) produced in 1871 more than 4,000 tons, of which 3,300 were shipped to Cleveland. (Mines Branch Summary Report 1909, p. 112.) In the same year, the Chaffey mine, about half-a-mile distant, shipped about 11,000 tons to

Cleveland. This ore carries 9.80% TiO_2. There are also several other considerable deposits in Eastern Ontario, in Renfrew, Hastings, and Haliburton Counties. Farther west, outcrops of titaniferous magnetites are found near Latchford, Chapleau, and in the Soo District. Probably the largest known ore-body of this kind in Ontario is found in the Rainy Lake district near Seine Bay, where there is a range twelve miles long with numerous outcrops ranging from 10 ft. to 61 ft. wide of solid ore, with lean ore showing in some places a hundred feet and upwards in width (Fe 45 to 50%, TiO_2 10 to 28%).

The occurrences in Quebec are well known, including large ore-bodies in Saguenay Co. (Fe-50 to 52%, TiO_2—17 to 21%), in St. Maurice Co. (Fe 41.5%, TiO_2, 7.5%), Terrebonne Co. (Fe 42.87%, TiO_2, 9.4%), at Baie St. Paul (ilmenite, Fe 47 to 48%, TiO_2, 25 to 35%). The deposits of ilmenite at Baie St. Paul and Ivry have been used as ores of titanium. An interesting occurrence is that in Beauce Co., 5½ miles from Beauceville, the ore occurring in pockets and stringers in serpentine rock. Some pockets are chromiferous (6.80%) while others are not.

This slight sketch of known occurrences of titaniferous ores in Canada makes it rather probable that if these ores can be utilized as a source of iron, there will be large quantities to draw upon.

In the paper referred to, Rossi has set down the current objections to the use of titaniferous iron ores and the facts of his own experience and that of others. It may be worth while to review them here. He worked with ores carrying from 18% to 20% of titanic acid.

1. *Pasty slag.*—"As anybody who may desire to make the experiment can verify, titanic acid can form definite compounds, perfectly fusible, if properly fluxed, containing as much as 35 to 40 or even 50% of titanic acid, with alumina, lime, and magnesia as bases, and admissible as slags in blast furnace work. . . The objections to the smelting of titaniferous ores on account of the refractory character of the slags are not sustained by our practice or that of others, or by direct experiments on the properties of these compounds."

Dr. Stansfield has extended our acquaintance with this part of the subject by a research in which he has shown that there is a rather wide range of fusible slags which can be made with silica as a flux. In this case *titania* (a name proposed by Dr. Stansfield instead of *titanic acid*) acts as a base.

A few examples will illustrate:

TiO_2	20%	softens at 1275°
Al_2O_3	10	
Ca O	10	
SiO_2	60	
	100	
TiO_2	30%	softens at 1250°
Al_2O_3	10	
Ca O	10	
SiO_2	50	
	100	
TiO_2	20%	softens at 1270°
Al_2O_3	10	
Ca O	30	
SiO_2	40	
	100	

In Rossi's practice it was treated as an acid constituent of the slag. It seems to resemble alumina in the power to act in either capacity. This agrees with our knowledge of it in chemical practice.

2. *Deposits of Infusible Titanium Cyanonitride.*—This beautiful copper-colored compound attracted early attention in blast furnaces. It was at first mistaken for iron pyrites. In 1822 Wollaston found titanium in it and decided that it was the element itself. It was not till 1849 that Woehler made a complete analysis and determined the formula—Ti

$(CN)_2$, 3 Ti_3 N_2. Its infusibility causes it at times to collect in solid masses in the blast furnace, and pieces weighing 80 lbs. and upwards have been found. Rossi writes of this difficulty as follows;—"In running a furnace under special conditions of temperature and pressure of blast, no troubles have been experienced from the titanium deposits. We never observed any in our blast furnace tests, and none is mentioned by Dr. Forbes in his practice in England and Norway." It is quite possible that this feature of the bad repute of titaniferous ores came from the presence of the coppery material in furnaces which 'froze' from other causes.

3. *Lower Temperature necessary.*—This is thought to be necessary in order to avoid excessive reduction of titanium and to permit the reduction of silicon. Rossi writes, "If these conditions of lower heat, considered more favorable in smelting these ores, are held to imply against them a waste of fuel, it is a question whether this is not offset by the smaller amount of cinder to melt, the lesser quantity of fluxes necessary, and their indirect effect upon the productive capacity of the furnace, as well as the greater value of the pig metal obtained for specific and numerous applications.[1] This is without taking into account the possibility of not submitting to it (the conditions mentioned) by a rapid driving and forcing the production, conditions which, to judge from our tests, could be easily realized with these ores." In another place Rossi states that he found no excessive consumption of fuel, but the contrary.

Rossi devoted a large part of his life to these investigations and in spite of the success which he states he had with these ores, he did not succeed in persuading furnace men to believe in their easy and profitable reduction. It is pleasant to know that his fortune has been better than that of many other enthusiastic pioneers, his researches on titaniferous iron ores having led to the profitable manufacture of ferro-carbotitanium, and other titanium alloys.

[1]The superior properties of this pig iron were recognized at least 58 years ago. In 1861 Robert Mushet took out a patent for "smelting ilmenite and hematite of Lancashire and Cumberland, so as to produce in the blast furnace an alloy of titanium, iron and carbon, possessing properties which render it superior to ordinary pig iron."

The experimental run in 1914 on the Sanford Hill (Adirondacks) concentrate carrying 55% iron and 11½% titanic acid showed that magnetite mixed with varying amounts of the concentrate up to five-sixteenths was easily melted. The slag was unusually fusible and the fuel consumption normal. But it was difficult to make pig containing 2% of silicon or over, as titanium reduced and replaced the silicon. This mixture of ore would carry about 3½% of titanic acid. It has lately come to be acknowledged that up to this limit titanic acid offers no obstacles in furnace practice. If we had an abundance of other iron ores it might become the practice in this country to mix with them the titaniferous ores on account of their usual freedom from phosphorous and sulphur and the excellent quality of pig they make. By the way, the titaniferous ores are not always free from phosphorus. In a recent investigation of the New Zealand iron sands found at Taranaki, it was unexpectedly found that every sample was high in phosphorus,—ranging from 0.1% to 0.18%.

There is another chance for our titaniferous ores,—direct smelting in electric furnaces. As is well known Mr. J. W. Evans, of Belleville, has been a pioneer in this, and in conjunction with Dr. Alfred Stansfield, has worked out a process which is very promising. As both Evans and Stansfield have published papers on the subject, it will not be necessary here to do more than sum up Dr. Stansfield's conclusions:—

1. No limits to the percentage of titanic acid in ores suitable for electric smelting, but costs will increase.

2. Probable that process will be applied to ores containing from 5% to 10% of titanium. Ores higher in titanium may in some cases be concentrated magnetically. Tailing may be rich enough in titanium to manufacture ferro-titanium.

3. Electric furnace more suitable than the blast furnace for smelting pulverized ores.

4. The use of titaniferous ores for making tool steel, and steel castings would appear to be very advantageous commercially.

5. Every probability that a process which yields steel instead of pig iron would be commercially possible in favorable localities.

The investigations of Huppertz and Lugner seem to have escaped general notice. Their researches showed that there was no difficulty in reducing titaniferous iron ores in the electrical furnace so as to produce iron with very little titanium, and at the same time a slag containing practically all the titanium. Below 2,000° and in the absence of nitrogen which in the blast furnace causes the formation of titanium nitride and cyanonitride, only a vanishing quantity of titanium is reduced. The process would offer no difficulty, were it not that the charcoal or coke tends to separate by coming to the surface, and the consequent slow reduction causes excessive expenditure of energy. To remedy this they reduce the slag to titanium carbide, etc., a very powerful and heavier reducing agent. When the ore, melted in another furnace, is run into this, reduction takes place very quickly. The slag for this process is made by using an insufficient quantity of charcoal to reduce all the iron in the ore. The slag so obtained is very fusible. It contains from 40% to 47% of titania, from 20% to 25% of silica, and from 30% to 34% of ferrous oxide. They estimate that to produce 1 ton of pure iron or steel requires from 0.3 to 0.4 electrical horse-power year. In a favorable locality in this country, the cost for power would be, I suppose, five or six dollars. This process is ingenious, and apparently involves a new principle.

As Rossi has pointed out, it is possible to smelt titaniferous iron ores in such a way as to make a slag very high in titania. The electric furnace offers no difficulties in doing this, and the results of Huppertz and Lugner point to the possibility of getting as a by-product a slag which might be a suitable starting point for the manufacture of ferro-carbotitanium, the use of which as a cleanser for steel is still very large, although apparently declining. Such a slag might also be a cheap raw material for the manufacture of the titanium compounds which are used in tanning, dyeing, and various other industries. Many of these applications requiring pure titanium compounds would be extended and new ones found, if the materials were made available at

reasonable prices. Considering the great abundance and wide distribution of titaniferous iron ores, the superior quality of the iron and steel made from them, and the possibilities of by-products, one may hope for a more general use of such ores in the near future. In this connection one should not forget that it is possible to make red, orange, and yellow paints by roasting titaniferous iron ores under suitable conditions. Rossi has worked out a process for making a white paint of superior covering power and great durability by precipitating titanic acid in a pure state. The writer has learned from a personal letter that this new white paint will be on the market within a year. A recent report states that a Norwegian company is now putting on the market a titanium white, probably similar to Rossi's. It is well known that the covering power of a paint depends in part on the refractive index of the particles of solid. This property is very high in titanic acid, which is therefore also particularly well suited as a substitute for oxide of tin etc., in making enamels. The only objection to its use in enamels is the yellow tint imparted. It should be possible to correct this by using a very small proportion of cobalt oxide.

Another point of interest in these ores is the almost constant presence of vanadium, which indeed is not uncommon in other iron ores. One recalls that it was first discovered in the ores of Taberg, Sweden. In Canadian titaniferous ores it is found pretty constantly, so far as tested for, in amounts running from 0.05% to 0.6%, or even higher in some grab samples tested in our laboratories. At present prices of vanadium these amounts represent values of $3 to $36 in a ton of ore. The vanadium is reduced, and goes into the pig, but in refining, it is nearly all lost in the slag. An interesting account of this is published in the Journal of the Iron and Steel Institute (1915, II, p.221). The minette ores of France, etc., carry 0.068 to 0.102% of vanadium. This enters partly into the pig and is partly slagged off, the pig, however, carrying 0.181%. In refining, the vanadium is easily oxidized and goes into the slag, so that the steel shows only 0.007 to 0.003%, while the converter slag gave an average of 0.87%. The Germans reported during the war that they were getting all the vanadium they needed from an iron slag containing

not more than 0.7%. One wonders if it was from the minette ores, and what the process of extraction from the slag was. If it were possible (or rather if some one would find out how to do it) to get the vanadium of the titaniferous iron ores into finished steel without going through the expensive wet process of extraction, we could make a great deal of vanadium steel in Canada. We should remember, too, that Canada has some of the few workable deposits of chrome iron ore, which would give us the second alloy material for this popular steel.

J. Baxeres de Alzugaray, who experimented with Swedish ores in England twenty-five years ago, recovered in the pig iron almost all the titanium and vanadium contained in the ores.

The pig analysed as follows:—

Carbon	3.28%
Silicon	2.60
Sulphur	0.05
Phosphorus	0.04
Titanium	3.03
Vanadium	0.35
Manganese	0.60
Iron	89.95
	99.90

Basic open-hearth steel of very high grade was made, using as part of the charge some of this pig. The steel analysed as follows:—

Iron	98.620
Carbon	0.180
Silicon	0.100
Sulphur	0.030
Phosphorus	0.020
Titanium	0.120
Vanadium	0.230
Manganese	0.700
	100.000

Alzugaray gives no further particulars of this run. In connection with his success in keeping the vanadium in the steel he writes:—

"Metallurgical problems are first usually attacked by round-about and complicated methods, instead of by direct and simple methods. Thus, instead of making from iron ores containing vanadium the alloy steel direct, we make ferro-vanadium from expensive ores and add it to steel. The same can be said of ferro-titanium. [*Mining and Engineering World*, Vol. 41 G(1914), pp. 889-890.]

When a simple process has been put in operation whereby the titanium and vanadium in our titaniferous ores are both made use of directly in making pure alloy steel, then central Canada will take her place among the iron producing districts of the world.

DISCUSSION

MR. JOHN A. DRESSER: Does Dr. Goodwin anticipate that ores high in titanium will be utilized earlier than those low in titanium? We have in central Canada huge bodies of ore of which titania forms up to 35 to 40%, the balance being mainly iron oxide. From which direction is this problem most likely to be attacked, for the value in iron or in titania?

DR. GOODWIN: I cannot pretend to be an expert. I have looked into it as a student would and I notice there is no difficulty at present about ores of lower content. Furnace men accept anything up to 3½% as perfectly safe at present. I have been given that impression, but I don't know whether that would be agreed to by furnace men here to-day. With regard to ores of high content, they could be utilized probably as a source not only of iron and steel, but of titanium compounds as well. Rossi's company at Niagara Falls has been working for some time on a process for extracting titania and for precipitating it in such a form that it makes a very high-class white paint which is superior to white lead in its covering power

and which also is absolutely resistant to all those influences which spoil white lead. This would be a very valuable by-product. It is well known that ores of higher content can be used as a raw material for manufacturing other kinds of paint and all those titanium compounds which are used in the textile industry. I could not possibly predict whether the lower ones would be generally used in this connection, unless it were on account of the higher ones being used for other purposes.

MR. J. W. EVANS: There is certainly a great field for the utilization of titaniferous iron ores. They are generally free from sulphur and phosphorus and contain elements which are of great value in alloy steels. It takes a long time to educate blast furnace men regarding the values of these ores. I have tried many times to induce them to try these titaniferous ores mixed with their regular furnace burden, but without success. One manager took a carload and put it through the blast furnace, mixing one of titaniferous to three of his regular ore. He said that it worked very well in the furnace, and he did not notice any difference in the operation, but, as he did not keep the pig-iron separate, I could not get any of it for analysis. The present manager of the works in question will not look at titaniferous ores at all while he can obtain hematite. Personally, I have great faith that in time the good qualities of the titaniferous ores will be recognized.

MR. G. C. MACKENZIE: Dr. Goodwin has reviewed this subject at some length. Possibly he may have overlooked the fact that only a few years ago at Crown Point, N.Y., Mr. Bauchman ran one of the furnaces of the Northern Iron Company for about two months on titaniferous iron ores. I heard Mr. Bauchman read a paper on this subject before the American Iron and Steel Institute in 1914. This paper is published in the proceedings of the American Iron and Steel Institute. It is some time since I have read the paper, but I recollect that he had no difficulty at all in operating his furnace on mixtures running as high as 6% titanic acid, and the only reason the experiments were not continued was that the term of the furnace lease ran out. It is a very large problem and I would not expect much hope of success working on a small scale. Dr.

Rossi, like many others who have undertaken research work, was always hampered for lack of funds. The old gentleman always worked under extreme difficulties. When Mr. Bauchman undertook his experiments at Crown Point, he had a considerable amount of money, a modern furnace and plenty of ore, all very essential for experimental work on a problem of this nature. Perhaps the Advisory Council of Scientific Research would undertake problems of this character and magnitude. If the Council are prepared to spend several million dollars for operating blast furnaces for a year or two, I am sure they would arrive at some most interesting conclusions.

The objection to titaniferous iron ores by furnace men is mainly attributable to inexperience. I remember meeting the late Mr. Hill, blast furnace superintendent for the Pennsylvania Steel Company, at Lebanon, Pa., who told me that he ran some of the furnaces of the Colorado Steel and Iron Co. on ore mixtures containing 6% TiO_2 and had experienced no difficulty. Because he could secure other ores free from titanium, his company objected to his continuing the practice. There seems to be a general belief that an ore mixture containing 6 to 8% TiO_2 can be handled in the blast furnace with a proper understanding of the problem involved.

I remember the late Mr. John J. Drummond telling me that some years ago they had run the little Radnor charcoal-iron furnace on 'straight' titaniferous ore containing 20% TiO_2. They used a certain proportion of rock salt as a flux and made some wonderful pig-iron which could hardly be broken. Some of the iron was sent to Sheffield and the reports on its performance were very good. Unfortunately, I never got the records of this experiment from him, but I have no doubt these records are on file somewhere and any one interested could get them.

DR. JAMES F. KEMP: I knew Mr. Rossi very well twenty years ago, and at that time, as I was studying the titaniferous ores of the Adirondacks, I discussed his experiments often with him. The line which he took in his smelting was this: He knew that there was a variety or close relative of the mineral titanite, the silico-titanate of lime, which was quite fusible. I think it is called keilhauite. Mr. Rossi, therefore, calculated

his slag to correspond with it, leaving out the yttria, and figured his titania as so much silica. He believed that the difficulties met by the older furnace men were due to their failure to consider the titania as silica. In a small shaft furnace in Buffalo, which was, I believe, a remodelled cupola, he had no difficulty in producing a very high-grade pig-iron from Lake Sanford ore. As I recall, his stack was only 20 or 25 feet high.

The campaign carried on by Mr. Bauchman in the blast furnace at Port Henry was much more elaborate, and was based on the same ores from Lake Sanford. As the last speaker has said, no serious difficulties were met, proper provision having been made for the character of the ore. The chief difficulty in the way of utilizing the titaniferous ores at Lake Sanford, at the headwaters of the Hudson in the heart of the Adirondacks, lies in transportation. Across the natural and easy line for a railway from the south are two townships of State land, acquired in the interests of the State Forest Preserve, through which the State Constitution forbids the construction of any new railways. No other practicable way out has yet developed or been utilized, although the ores are not specially high in titanium and, as is the case with almost, but not quite all, titaniferous ores, they are very low in phosphorus. The amount of ore is very large and some day in the future we may hope that these important reserves may be utilized.

MR. H. B. GREENSTED: I think that perhaps blast furnace men are unduly prejudiced against the use of titaniferous iron ores; but I feel that their prejudice exists to a large extent, not so much on account of a small titanium content, but because the majority of titaniferous ores are magnetites and, on account of their physical characteristics, are much more difficult to smelt. So far as the titaniferous ores themselves are concerned, the prejudice exists on account of the tendency of these ores to cause a building up on the furnace bottoms, but that would probably not occur if the furnace man knew he was handling titania and made proper allowance for it in calculating his slag. I have had something to do with the titaniferous ores of New York State, and they were successfully smelted in furnaces in eastern Pennsylvania. But the undertaking was difficult in that the

ores were so finely divided in the rock, that after magnetic separation, while high in iron, and not too high in titania, were still subject to prejudice as they were then too fine. On the other hand, if we have a titaniferous ore of massive nature, the furnace man objects on account of the high fuel consumption necessary to reduce it. Nevertheless, I believe the prejudice is due rather to the physical condition of the ore than to its chemical composition, for the majority of magnetic iron ores require so much more coke to reduce them than do hematites of similar composition. We handled successfully one of the Lake Superior hematites containing titania and there was no difficulty whatever in reducing it, but we were requested not to mention the fact that titanium was present to others, but if these same people had endeavored to sell a magnetic ore of the same grade containing titania, it would have been rather more difficult. But the mere fact that the hematite contained titania was apparently enough to condemn the ore solely on account of the existing prejudice. Whether it is just or unjust is hard to determine, but I believe the feeling should not be laid entirely to the existence of titania in the ores, but rather that the majority of titaniferous ores are difficult to smelt on account of their physical characteristics, and it will take a long time to convince the average furnace man that titaniferous ores are good ores. Before these ores are worked commercially, a long campaign of education will be necessary, and it will only succeed when other ores are not readily available.

MR. MACKENZIE: The last speaker talked about the objection to titaniferous ores because they are usually magnetic. There is a great deal of truth in that statement. Magnetites are generally looked upon by furnace men as objectionable. There has been a very strong prejudice growing up which is hard to overcome, and when you talk to a furnace man on this side of the line about the use of domestic magnetites, you will make very little headway. He has probably been induced at some time or other to use 10 or 15 per cent magnetites with his hematite lake ores, and naturally he gets into trouble because his furnace is then working on two different oxides that require different reducing conditions, the result being that he loses

control of his furnace. He, unfortunately, knows very little about the subject and as he cannot afford to experiment further he forthwith damns the magnetite. If examination is made of the records of the New York furnaces where they use a magnetite burden only, it will be found that the coke consumption is a little higher than in hematite furnaces, but even at that, it isn't out of the way. The coke consumption is usually 2,200, 2,300 and occasionally 2,400 pounds per ton of iron. The Swedes have had no trouble in running their furnaces on straight magnetites, and it is only when furnace men attempt to mix hematites with magnetites that they get into trouble. British Columbian people talk about helping out their magnetite supply with hematite, but if they adopt that policy they most assuredly are building trouble for the first furnace that operates on the coast.

DR. ALFRED STANSFIELD (*communication to the Secretary*): The large scale blast furnace experiments mentioned by Mr. Mackenzie had developed at least one definite point which appeared to have been overlooked by the gentlemen who took part in the discussion. Thus, Mr. Mackenzie, referring to these experiments, stated that no difficulty had been found in operating the blast furnace on mixtures running as high as six per cent titanic acid. While it is no doubt correct that such mixtures could be smelted in the blast furnace, it was definitely established that they could not be smelted for the production of foundry pig-iron; the only possible product being a white or low silicon iron. Apparently when the furnace is operated in a way suitable for the production of foundry iron, too much titanium is reduced and infusible products are formed which block the furnace. This limitation in regard to the smelting of titaniferous ores must be carefully borne in mind in any work undertaken with a view to their utilization. With regard to the fluxes suitable for such ores, the experiments carried on in my laboratory by Mr. W. A. Wissler afford very valuable information which was not previously available. The results obtained were published in a paper before the Royal Society in 1916, and in this paper a chart is given showing the softening temperatures of mixtures of silica, lime, and titania containing in each case ten per cent of alumina.

IRON DEPOSITS ON THE BELCHER ISLANDS, HUDSON BAY

By E. S. Moore

(Annual Meeting, Montreal, March, 1919)

The Belcher Islands comprise a large group lying off the southeast coast of Hudson Bay. They are about seventy miles northwestward from Great Whale River (the best-known of the Hudson's Bay Company's posts in this region) and approximately five hundred miles a little south of east from Port Nelson on the west coast of the bay. From astronomic observations made by Mr. Howard, D.L.S., their location is approximately limited by 55°32′ and 56°42′ north latitude and 72°29′ and 80°55′ west longitude. Our information concerning the geography of the islands is due largely to the work of Mr. R. J. Flaherty, who was in charge of the Mackenzie Expedition, which for several years carried on exploratory operations in the Hudson Bay region. Previous to that time the islands were little known except to a few of the traders in the bay. Mr. Flaherty has recently published the results of his geographical work,[1] and the accompanying map (Fig. 1), with minor changes, was furnished by him for the work of the writer while examining, in conjunction with Mr. R. H. Flaherty, the iron deposits on the islands. This is a reconnaissance map, and therefore the scale of miles is probably not very accurate, but it outlines the islands in a very satisfactory manner and serves as a good guide for travelling about them. A comparison of this map with other maps of the Belchers will show a very marked difference between the present and past ideas of geographers on their outline and extent.

The writer's experience with the islands was gained in the summer of 1916, when examining the large areas of iron formation which occur there, and to Sir William Mackenzie his thanks are due for permission to publish the results of this geological investigation.

[1] R. J. Flaherty. "The Belcher Islands of Hudson Bay." The Geographical Review, June, 1918, p. 433.

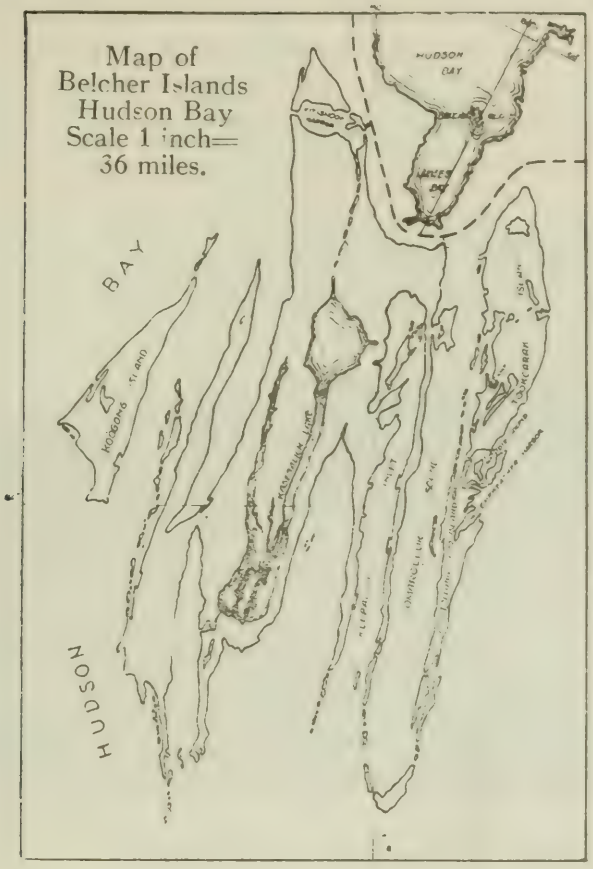


Fig. 1—Outline map of the Belcher Islands, Hudson Bay.

TOPOGRAPHIC FEATURES OF THE ISLANDS

These islands are comparatively low ridges rising to an altitude of only 450 feet in the highest point measured, and at few points do they exceed 250 feet. Owing to the fact that they consist chiefly of gently folded sediments, lava flows, and intrusive sheets, they form long, parallel ridges separated by deep bays. The water in these bays is in many places sufficiently deep to allow the entrance of large steamers, and some of them would furnish good harbours. The narrow peninsulas of diabase and basalt weather into ridges of rounded knobs, while the land masses, consisting of sedimentary rocks or of sediments overlain by lava flows, in most places expose rugged cliff-faces to the sea. The main ridges have a backbone of igneous rock.

There are no trees on the islands, since they lie within the treeless zone, and the only vegetation is moss and other small plants, of which there is quite a variety. Over large areas the rocks are as bare as if recently glaciated, and the vegetation is largely confined to glacial drift and sediment-filled depressions

Fig. 2.—Large flow of basalt overlying jasper on east side of Kasegalick lake.

between bare rocky ridges. On most of the islands of the group the geological features are exposed like an open book. The depressions are occupied by lakes, which everywhere dot the surface of the islands. One of them, Kasegalick Lake, is of large size, measuring approximately forty miles in length.

ROCK FORMATIONS AND THEIR STRUCTURE

The majority of the rocks of these islands are sedimentary but interbedded with them as sills and overlying them as flows are large sheets of igneous rock making up a series of great thickness very similar to some of the rocks, of the Lake Superior region. The sedimentary rocks to which the writer has applied the name Belcher series consist of graywacke, arkose, slate, sandstone, quartzite, jasper, limestone, and dolomite, having a thickness of approximately 9,000 feet. The limestone is

remarkable because of an extraordinary development of algal concretions, which form hundreds of feet of rock. These have been described at length in a previous article,[2] and anyone desiring a more detailed account of the geology of the islands is referred to that publication.

The igneous rocks are basalt and diabase very similar to the Keweenawan rocks of the Lake Superior region. The flows are amygdaloidal, and over large areas they show very distinct, ellipsoidal structure. These rocks have been designated the Tookcarak basalt and diabase because of their abundance on Tookcarak Island.

A large flow seems to have spread at one time practically all over the islands. This flow now caps the iron-formation in many places and has protected it from erosion. It is the youngest consolidated rock in the region.

The geological structure of the islands is comparatively simple, as the rocks have been bent into simple folds with large pitching anticlines and synclines. The islands originated as a result of this folding, as this process brought above the surface of the sea the series of rocks exposed around Richmond Gulf on the east coast of Hudson Bay and on the Manitounick and Nastapoka chains of islands along the coast. There are certain features which make it possible to correlate the formations on the Belcher Islands with the Nastapoka and Richmond groups of rocks, as Leith[3] has named those in the areas above mentioned. The iron-formation is similar to that along the east coast, and the algal limestones also may be seen just northward from the mouth of Great Whale River.

GEOLOGICAL AGE OF THE ROCKS

The problem of the age of these rocks is a very interesting one because of their relations to the iron-bearing formations of the Lake Superior region. They have been variously regarded

[2] Moore, E. S. "The Iron Formation on Belcher Islands, Hudson Bay, with Special Reference to its Origin and its Associated Algal Limestones." Jour. of Geol., Vol, XVI, 1918, pp, 412-438.

[3] Leith, C. K. "An Algonkian Basin in Hudson Bay." Economic Geology Vol. V., 1910, pp. 227-246.

as Cambrian, Upper Huronian, and early pre-Cambrian. The writer is in perfect accord with Dr. Leith, who considers them as late pre-Cambrian. There is no way of proving that they are of the same age as the rocks of the Lake Superior region, since the two basins are so widely separated, but their lithological character, their relation to the older gneisses, and other features would make any student of pre-Cambrian geology consider them as belonging somewhere in the later pre-Cambrian. The occurrence of such large areas of jasper, which is peculiarly characteristic of the pre-Cambrian, not only on this continent but on all or nearly all continents of the globe, is a very important feature in considering the age of these rocks. The large sills and flows of amygdaloidal basalt and diabase, so similar to the Keweenawan rocks of the Lake Superior region, are also interesting in this connection, especially when traces of cobalt in the form of smaltite, and small quantities of copper as chalcopyrite, occur with these igneous rocks. This occurrence of Keweenawan rocks points to a great petrographic province extending from the Lake Superior basin through the Sudbury and Cobalt districts northward into Hudson Bay and even far to the northwestward from this bay. We hope that we may be permitted sometime in the future to add the Hudson Bay area to the Cobalt, Sudbury and Keweenaw Peninsula areas as part of one great metallogenetic province.

The question as to whether the igneous rocks are everywhere later than the sediments has not been finally determined. On this point hangs the decision as to whether the sediments are Animikie, or contemporaneous with the igneous rocks and therefore Keweenawan in age, since one may feel justified in regarding the igneous rocks as of that age.

THE IRON-FORMATION: ITS CHARACTER AND DISTRIBUTION

The term iron-formation is used here, as in most writings on the Lake Superior district, to indicate a formation carrying sufficient iron to distinguish it from adjacent formations on the basis of its greater iron content. The iron may vary from that in good ore to that in rock only colored red by oxide.

The iron-formation on the Belcher Islands consists of hematite, jasper or jaspilite, magnetite, cherts free from iron, cherty iron-carbonate, cherty iron-silicate, bands of slate, gray-

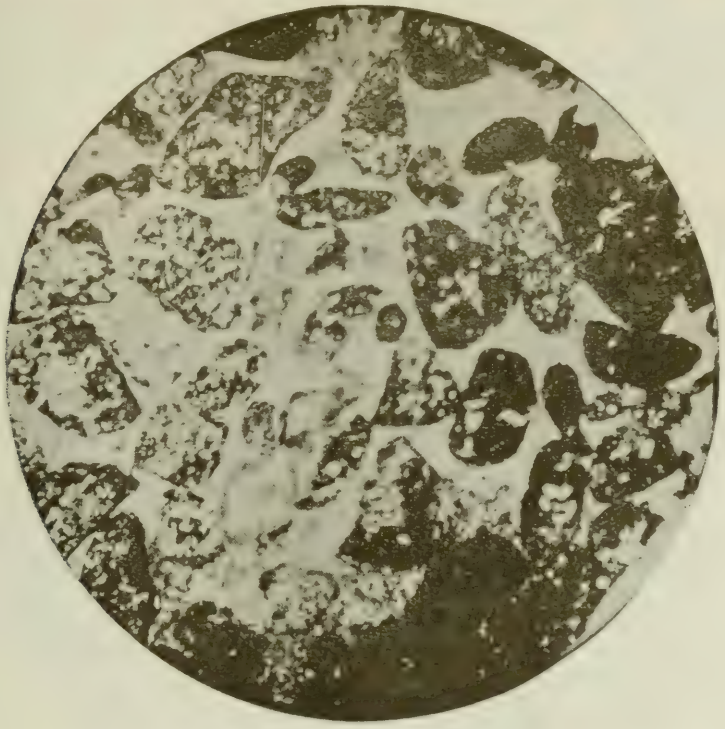


Fig. 3.

A.—Photomicrograph of siliceous granules from the iron-formation. The largest is 1.9 mm. in length.

wacke, and limestone. Throughout there is a marked similarity between this formation and the iron-formations of the Upper Huronian in the Lake Superior region. The discovery of abundant green granules like the greenalite granules of the Mesabi range serves to increase their similarity. These granules are colourless, reddish, reddish-brown, dark brown, and apple-green, depending upon their composition, which may be silica, calcite, hematite, limonite, or iron silicate. The silicate more nearly approaches the greenalite of the Mesabi range than it does any of the other iron silicates which commonly occur in the iron formations, such as thuringite or chamosite. In size the largest granules do not exceed two millimeters in diameter. In shape they vary greatly, being spherical, triangular, balloon-shaped,

ham-shaped, and ovoid. They are abundant in many places and grade with loss of distinctness in form into the ore.

The iron-formation is widely distributed over the islands. Beginning with comparatively lean jasper, it underlies a great cap of basalt where it dips gently beneath the sea toward the mainland on the east side of Tookcarak Island. Since this

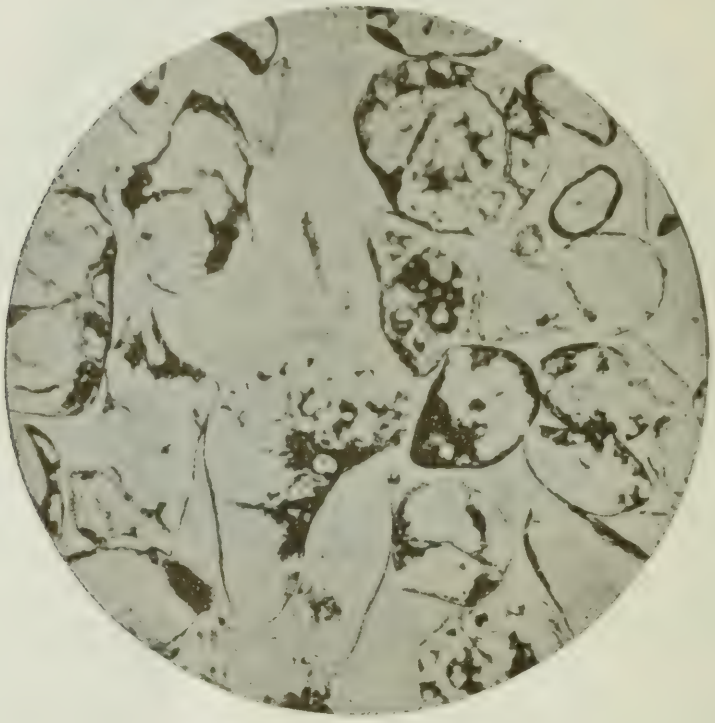


Fig. 3.

B.—Photomicrograph of hematite and greenalite granules varying from red to apple-green in colour. Silica arranged in a cell-like structure. Largest granule is 0.9 mm. in diameter. From the iron-formation.

island is a large anticline the formation follows around its ends and dips steeply westward along its western border. It rises from the syncline on the east side of Keepalloo Inlet, where the best grade of ore is found, and then dips very gently again on the east side of Kasegalick Lake, which lies on the west side of another great anticline. Around this lake the formation is leaner than on the east side of the anticline and so far as known there is no iron-formation of importance west of this line. The

maximum thickness of the formation does not exceed 275 feet.

ORIGIN OF THE IRON-FORMATION

The subject of the origin of the iron-formation has been discussed at length in the paper on the Belcher Islands previously mentioned, and it is not necessary to repeat that discussion in detail, but a summary of the general conclusions reached is given here.

The unusual occurrence of thick beds of concretions in the limestones, which are generally regarded as of algal origin, and the abundance of the small concretionary granules in associated rocks, suggests an organic origin for all these concretions. It is seen that in many of the granule calcite concretions have been replaced by silica and iron oxide, and from the similarity of these calcite concretions to recent ones of the same composition which are known to be of organic origin, it may be inferred that algæ have been instrumental in forming them. After their formation the replacement process occurred. It is also inferred that in view of the recent work of various investigators the iron bacteria are capable of precipitating iron from solution in such a manner as to form concretions. There may,

Fig. 4.—Large outcrop of iron-formation, northeast shore of Keepalloo Inlet.

therefore, have been some concretions of iron oxide deposited directly on the bottom of the body of water in which the iron-formation was deposited.

As to the source of the iron it is believed that it was furnished chiefly through the weathering of the basic igneous rocks of the earlier pre-Cambrian. In this regard the writer differs in opinion from Dr. Leith, who ascribes the source of the iron in similar rocks chiefly to magmatic waters which accompanied the igneous rocks associated with the sediments. The relation of the sediments to the intrusions and extrusions does not seem, however, in the opinion of the writer, to warrant this assumption for the iron-formation of the Belcher Islands.

The source of the cryptocrystalline silica would be found in fine clastic sediments from the acid rocks of the lands surrounding the basin and in silica set free, in the colloidal form, from weathered silicates and carried in solution to the basin.

Both iron and silica in the colloidal form would be deposited in the basin through the action of iron bacteria oxidizing the iron, and through decaying vegetable matter supplying carbon dioxide, which in the presence of calcium carbonate throws colloidal silica out of solution. The banding of the silica and iron deposits might therefore be seasonal and it would become more distinct through metamorphism, which would tend to increase the segregation of like materials into bands, during recrystallization. The deposits of iron of lateritic nature which are known to have been formed in tropical and subtropical regions through weathering processes are of sufficient magnitude to justify the assumption that weathering alone may have furnished the iron for our pre-Cambrian deposits. The writer, however, does not regard them as true laterites, but rather as being of the nature of lateritic material which has been carried to the sea and inland bodies of water as a combination of chemical and mechanical sediments, and which has been rearranged to a considerable extent through metamorphism.

ECONOMIC POSSIBILITIES OF THE BELCHER ISLANDS

No geologist or mining engineer, familiar with the Lake Superior iron ranges, and visiting these Islands, could fail to

have his curiosity aroused over the striking exposures of jasper which occur there. The lack of vegetation and consequent bareness of the formations probably give one the impression that the strongly coloured jasper forms a much larger proportion of the rocks that it really does, but in spite of that, the wide distribution of the iron-formation and its location on hillsides and on the flanks of synclines combine to produce conditions so favourable for the concentration of ore bodies, that it is surprising that important bodies do not occur. The iron-formation is not very thick, but stil thick enough to furnish a great deal of ore if it had been concentrated by natural processes. The greater part of the formation is, however, very lean siliceous material. The best area so far found lies along the northeast shore of Keepalloo Inlet, and the following section was obtained between the quartzite at sea level and the basalt flow capping the iron-formation 65 feet above sea level. The highest point in the hill is 270 feet above the sea The dip of the formation is very uniformly 43° eastward. The horizontal width of the outcrop is 358 feet, and the thicknesses of the various divisions are as given below:

		Feet
(a)	Basalt flow	
(b)	Peculiar cherty, sandy and calcareous rock carrying specks of hematite and magnetite, and weathering with rounded pits and irregular depressions. Microscope reveals granules of silica	63
(c)	Reddish to browish fissile shale	21
(d)	Jaspilite	37
(e)	Jaspilite with streaks of very lean ore	14
(f)	Hematite ore, some of it analysing as high as 50 per cent. iron	0.5
(g)	Jaspilite	6
(h)	Bluish hematite ore containing four narrow streaks, aggregating 6 inches of lean jasper	3.5
(i)	Lean, siliceous ore interbedded with jasper	6
(j)	Jasper	0.5
(k)	Lean ore	5
(l)	Jasper and jaspilite	54
(m)	Thin-bedded jasper with streaks of lean ore	12
(n)	Jaspilite	26
(o)	Shaly jasper	25
(p)	Quartzite	
	Total	273.5

The best sample of hematite ore which would be found in this section, and incidentally the best the writer found on the islands, analysed 50.70 per cent iron. Stories published by some people about vast quantities of ore of this, and higher, grade are entirely misleading. In most places the better-grade ore is interbedded with the lean, siliceous material in such a way as to make mining of the better material impossible.

An average sample was taken from a section 35 feet thick which represented the best part of the section mentioned above. This was all crushed, quartered, reduced, and analysed, the analysis being made by Professor C. E. McGuigg, who also made the other one quoted. The results were as follows:

	Per cent
Iron	30.10
Silica	37.97
Phosphorus	0.039
Sulphur	Trace

It will thus be seen that, while there are bands of low-grade ore in the iron-formation, the great bulk of this material is lean and siliceous like so much of the iron-formation in northern Canada. Along the strike these bands of ore form fingers running into the jasper. Some have reported innumerable tons of this ore lying loose on the surface almost at tide-water, and that, with such wonderful opportunities for the development of electric power on the mainland less than one hundred miles to the east, these deposits offer wonderful inducements. It is true that a large amount of power could be developed on the rivers emptying into the east side of the bay, as there are large waterfalls on them, but the climatic conditions would always be a great drawback to operating in that region, even if the ore were of a much higher grade. It is probable that as a rule the islands cannot be approached before July 10th, owing to the ice. While en route to the islands our party was caught in the pack ice near the centre of James Bay and held from July the first until the fifth, although the ice broke early that year. The propeller was broken from the ship, and our experiences were such as to satisfy us that unless

ships are specially constructed for work in ice, they run great risk in travelling in James or Hudson Bay before July 10th of most seasons, and the ice is reported to remain around the islands sometimes until August. This ice in the southern part of the bay is comparatively thin pack ice, but there is also always the risk of encountering the heavy glacier icebergs in the northern part of the bay and in the straits. Specially constructed ships might count on operating in the bay with reasonable safety, from early in July until the latter part of November of most years, but this period would be shortened or lengthened in abnormal seasons. The autumn months are said to be very stormy, with almost continuous gales.

It has been suggested that native labour could be employed in operating mines in this region. There is no doubt that some of the Eskimos on the islands and the mainland make very faithful workers for rough labour, but experience has shown that with the arrival of the white man the native soon degenerates and ceases to be much of a factor in the labour situation where large operations are being carried on.

The occurrence of cobalt in the form of smaltite and cobalt bloom in calcite veins on these islands is interesting because of its relations with rocks believed to be of the same age as those with which the silver and cobalt occur at Cobalt, Ontario, but so far nothing of any account has been found.

As already mentioned, chalcopyrite has been found. It occurs in metamorphosed limestone associated with a diabase sill. It was hoped that native copper might be found, since it occurs with similar rocks in the Lake Superior region and apparently along the Arctic coast in northern Canada. The copper so far found is not, however, of economic importance.

Taking all factors into consideration, it is the opinion of the writer that mining on the Belcher Islands cannot be considered as an economic possibility.

NOVA SCOTIAN OOLITIC IRON DEPOSITS OF SEDIMENTARY ORIGIN*

By Albert O. Hayes

(Annual Meeting, Mining Society of Nova Scotia, New Glasgow, April, 1919)

There are several occurrences of bedded iron deposits in Nova Scotia, which, while they have so far failed to compete with the Wabana iron ore in the open market, indicate the presence of ore formed under similar conditions and point to the possibility of richer ores being found when the country is more thoroughly prospected.

Bedded deposits of iron-bearing minerals in Nova Scotia were laid down as marine sediments in three successive periods of geological time in the Palæozoic era, and contain fossils of the early Ordovician, Middle Silurian and early Devonian epochs. Similar deposits of early Ordovician age occur in Newfoundland and form one of the largest iron ore reserves in the world; and the important Clinton ores of Silurian age in the eastern United States of the same type are also represented in Nova Scotia. A study of the Nictaux-Torbrook hematites and magnetites gives a clue to the origin of these Devonian deposits, and it may be useful to present descriptions of these Nova Scotian bedded iron ores.

Deposits of the Ordovician Period

Deposits of the Ordovician period occur in Cape Breton county south of the Mira river from Grand Mira to Marion Bridge; in Antigonish county at Doctor's brook and Brown's mountain; and in Pictou county at Piedmont.

Grand Mira, Cape Breton County.—Several beds of oolitic hematite which grades into magnetite, the thickest of which exposed at the time of the writer's examination measured one foot 7 inches, occur in folded strata on the farm of John Gillis at Grand Mira, and are thought to extend north-northeastward towards Marion Bridge. Similar deposits were found south of the

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French road about 1½ miles from John Gillis' farm where five beds of magnetite are reported to be 4½, 7, 10, 14 and 18 inches thick respectively. Also on the farm of Donald McKiegan, 1½ miles north-northeast of the Grand Mira locality, several hematite beds occur, the thickest measuring 9¾ inches The iron-bearing beds are interstratified with sandstone and shale belonging to the Cambro-Ordovician group, and the measures are folded with steep dips; at Grand Mira the ferruginous beds appear to outcrop on both limbs of a synclinal fold. The strata forming the easterly limb are cut off by the plutonic rocks of the White Granite hills. A magnetometric map, surveyed by A. H. A. Robinson,[1] shows that magnetite occurs along the outcrops nearest the granite contact, while none was indicated along the outcrops farthest from the granite.

Fossil shell fragments too small for identification, and the comminuted remains of a small obolus like brachiopod, occur in the ferruginous beds at Grand Mira and at the McKiegan farm, Marion Bridge. These may be either Upper Cambrian or Lower Ordovician in age. G. F. Matthew[2] reports fossils from McNeil brook about one-quarter of a mile north of the iron-bearing beds including *Peltura Scarabeoides*, *Spharophthalmus alatus* and several *agnosti* and *Lingulellae*. This association of fossils is placed in the Bretonnian division of the St. John group and probably belongs to the Lower Ordovician rather than the Upper Cambrian epoch. Matthew[3] also described the iron deposits as hematite beds deposited under similar conditions to those of Bell island in Newfoundland.

E. Lindeman[4] states:—"At Grand Mira, on the other hand, the magnetite is found in narrow bands, associated with slates and quartzites of probably Cambrian age. Here it grades imperceptibly into hematite, and is undoubtedly of the same origin as the latter, that is, vein fillings or incomplete replacement of the stratified rocks by iron oxides.

[1]Canada Dept. of Mines, Mines Branch No. 313.
[2]Cambrian Rocks of Cape Breton. Geol. Surv. 1903.
[3]Geol. Surv. Can., Vol. XII, 1899, p. 188 A.
[4]Canada, Dept. of Mines, Mines Branch Summary Report 1913, p. 31.

"In none of the above mentioned localities has the magnetite been found in such a quantity as to render it of economic importance."

As a result of both field and microscopic examination, the writer agrees with the opinion expressed by G. F. Matthew that these iron deposits are of similar origin to the Wabana iron ore of Newfoundland,[5] as both are composed of the silicate of iron and alumina, hematite, siderite, quartz grains and shell fragments, all of which were originally laid down as shallow sea-bottom deposits. The magnetite appears to be an alteration product due to the intrusion of igneous rocks.

As yet a comparatively small section of the Cambro-Ordovician sediments has been carefully studied. In the similar Wabana deposits, ferruginous horizons with thin beds of hematite recur through about 2,000 feet thickness of strata in which there are only three workable beds. Careful stratigraphical comparisons between the Cape Breton and Newfoundland Cambro-Ordovician groups should be made before concluding that ferruginous beds of workable thickness are absent.

Arisaig, N.S.—The iron ore of Doctor's brook and Brown's mountain is described by M. Y. Williams as follows:

"Near Brown's Mountain post-office and in the locality of Doctor's brook, oolitic hematite is apparently interbedded with the greywacke of the lower formation of the Brown's mountain rocks. In the former locality the ore 'beds,' which are two or more in number, vary from about five to twenty feet or more in thickness. The ore is evidently very siliceous. A part of the thicker 'bed' is merely a grit impregnated with iron.

"The ore 'beds' of Doctor's brook vicinity are three in number and vary from two to eight feet in average thickness. The thickest 'bed' is very siliceous, but the thinner 'beds' are freely oolitic, sparingly fossiliferous, and contain a fair percentage of iron (40-48 per cent). The iron ore horizon is found near the base of the upper formation of the Brown's mountain group, which occupies a narrow belt to the south of the ore zone.

[5]For Description see A. O. Hayes Geol. Surv. Memoir 78.

The iron ore 'leads' have been traced for about three miles, the ore 'beds' being nearly vertical all the way. Numerous small faults intercept the ore and its thickness is variable.

"From the evidence obtained, the ore is most probably sedimentary, is of lower Ordovician age, and may be directly correlated with the bedded hematites of Great Belle Isle, Conception bay, Newfoundland. Small faults have been demonstrated as cutting the ore, but there appears to be no evidence of either extensive faulting or dislocation due to igneous intrusion between the east branch of Doctor's brook and the west brook flowing out of the Little hollow. The ore beds are on the north side of a syncline and probably extend downwards without any serious change in attitude for several hundred feet. The faulting of the region appears to be mainly vertical, so horizontal displacements are not thought probable, but may exist. Much ore is already in sight and the main considerations are those of grade of the ore and expense in mining and transportation."

I visited the Doctor's brook locality in 1916 and have recently studied the petrography of specimens collected there and agree with Dr. Williams' conclusions. It is similar to leaner portions of the Wabana ore containing the oxides and silicate of iron, detrital quartz and phosphatic shell fragments. No boring algæ were identified. One most striking evidence of the sedimentary origin of the iron is the occurrence of a conglomeratic portion of the ore, the pebbles of which are made up of masses of ferruginous spherules embedded in a siliceous matrix.

Piedmont, N.S.—A bed of oolitic hematite and chamosite seven feet thick is exposed for 50 feet along the strike. An average sample gave the following analysis[6]:—

SiO_2	21.24
Fe total	42.50
P	0.704
Ca O	6.46

[6]Geol. Surv. Can. (Summary Report for 1916, pp. 275-277.)

The ferruginous bed is composed of abundant detrital quartz grains in a matrix of a green iron silicate and hematite. These iron-bearing minerals occur largely in the form of spherules usually built around a quartz grain as a nucleus. They also occur in masses with no definite structure. Small aggregates of shell fragments occur scattered irregularly through the rock. These are too small to identify but are probably from fossil brachiopods identified by L. D. Burling to be *lingulella bella, Walcott*, similar to those found in the accompanying sediments. The *lingulellae* are composed largely of calcium phosphate and, therefore, would supply phosphorus distributed irregularly throughout the bed. Hexagonal plates of hematite occur in the green iron silicate and represent various stages of crystal growth. It is probable that both silicate and oxide are of sedimentary origin but that the silicate formed first, and the hematite developed later by oxidation, in the unconsolidated sediments.

The presence of several beds of iron ore interbedded in strata of the same age in each of the other localities in Cape Breton and Antigonish counties suggests that more beds may exist in the Piedmont locality hidden beneath the drift.

DEPOSITS OF THE SILURIAN PERIOD

Deposits of the Silurian period occur in Antigonish county exposed on Arisaig and Ross brooks and in Pictou county about three miles north of Sunnybrae on Blanchard brook.

Arisaig and Ross Brooks.—Williams describes the iron ore of Arisaig and Ross brooks as a bed varying two to three feet in thickness in a badly faulted zone and without doubt of sedimentary origin. They are placed in the McAdam formation, in age early Rochester or a little later than Upper Clinton, correlating with some of the Clinton ores of the Appalachian region in the United States. I found the ore to be composed of spherules of hematite and of a green iron silicate resembling that of the Wabana and Clinton ores; the latter is described by C. H. Smyth, Jr.[7] A small amount of detrital quartz and fossil

[7]The Clinton type of iron ore deposits—Types of Ore Deposits, edited by H. Foster Bain, pp. 35-52, 1911.

fragments accompany the iron minerals and form the nucleii of the spherules.

Blanchard Brook, Pictou County.—A bed of oolitic hematite about 18 inches thick appears to be very persistent in a synclinal fold about three miles north of Sunnybrae. I collected the following fossils from the ore and wall rocks which have been determined by Dr. F. H. McLearn and Dr. E. M. Kindle as follows:—

Cornulites Sp.
Leptaena Sp.
Stropheodonta Sp.
Camarotoechia nucula var. planorugosa
Meristina billingsiana

This is the fauna which characterizes the McAdam formation of the Arisaig section, and consequently indicates a southward extension of this ferruginous horizon.

In thin section this ore is also seen to be composed of spherules of hematite, and the green iron silicate resembling chamosite forms a large part of the matrix. Quartz and fossil fragments occur in varying amounts. Except for the character of the fossils the ore closely resembles the Wabana in structure and composition.

DEPOSITS OF THE DEVONIAN PERIOD

Bedded Iron Ores of Devonian Period.—Oriskany, or earlier, formations occur in Annapolis county at Clementsport and in the Nictaux-Torbrook[8] district.

Along the northern slope of South mountain a series of slates and quartzites, with interbedded iron ores, occurs. These have been synclinally folded, and locally crumpled, faulted, and sheared. The series is richly fossiliferous and has been correlated with the Oriskany stage of the Devonian period.

Dr. E. M. Kindle has kindly discussed the age of the ore-bearing beds as follows: "The 'shell ore' of the Nictaux

[8]Geol. Surv. Summary Report, 1916, p. 273.

mines contains an abundant fauna of lower Devonian age in which brachiopods are dominant. Ostracods and two or three species of gasteropods are also abundant in certain bands. Pelecypods and trilobites are comparatively rare. Among the species present in this fauna are the following:

Megalanterus cf. *ovalis*
Spirifer arenosus
Spirifer arrectus
Tentaculites elongatus
Bucania sp.
Beyrichia sp.

"This fauna shows both strong resemblances to and some contrasts with the Oriskany fauna. The latter are probably a consequent of the calcareous and argillaceous facies which the fauna represents. The fauna of the typical Oriskany deposits represents a highly arenaceous facies of the Helderbergian sea. The presence in the Nictaux fauna of such species as *Spirifer arenosus* and *Spirifer arrectus* appears to justify its correlation with the Oriskany.

"The question whether or not the New Scotland fauna is present in some of the other horizons of the Torbrook section must be left for future study and discussion."

Dykes and larger masses of gabbro and diorite have penetrated these sediments and become increasingly abundant to the south, where, about five miles southeast of the Annapolis river, the main body of the plutonic rocks which floor the greater part of the interior of the western portion of Nova Scotia, is found. Bordering the contact is a zone about one mile in width composed of about equal parts of granite and broken, twisted and metamorphosed sediments. Since portions of this granitic batholith are elsewhere overlain unconformably by Lower Carboniferous conglomerates, the intrusion is thought to have taken place in the Devonian period.

The iron ores occur as bedded deposits forming two nearly parallel zones about 5,000 feet apart. The southern zone,

locally called the South Mountain bed, has been traced and test pits sunk along its outcrop from the Annapolis-Kings County line about halfway between the Canaan and Messenger roads, for about five miles southwestward past Bloomington towards the Nictaux river.

The northern zone extends from Black river about half a mile north of the Messenger road to the west side of Nictaux river. The ore has been obtained principally from the Leckie bed and a small quantity from the overlying shell bed. Other beds, which have not produced any ore, occur in this zone.

According to the annual reports of the Nova Scotian Department of Mines, a total of 348,639 tons of ore was produced between the years 1891 and 1913. The mines are now idle and filled with water so that no underground study of the deposits could be made. The history and detailed descriptions of the mines, with mine plans, were published by Dr. J. E. Woodman[9] in his report on the iron ore deposits of Nova Scotia. The geology and stratigraphy of the iron ore series were described by Prof. L. W. Bailey[10] and Mr. Hugh Fletcher[11]. A magnetometric survey of the western portion of the Torbrook iron ore deposits was made by Mr. Howells Frechette[12] in 1910.

The South Mountain bed is a ferruginous quartzite composed of magnetite, green iron silicate, detrital quartz, and fine-grained argillaceous material. It is frequently oolitic and at the eastern exposures contains hematite. Examined in thin section the green iron silicate is seen to occur in the form of spherules and also interstitially as a cement. The magnetite occurs as small masses usually with crystalline outline and appears to be closely associated with the silicate, as an alteration product.

The rocks examined were considerably metamorphosed. Chemical analyses of samples taken from the various test pits

[9]Canada, Mines Branch, No. 20, 1909, pp. 48-170.
[10]Geol. Surv. Can. Ann. Rept., Vol. IX, 1896, pp. 1M9-123M.
[11]Geol. Surv. Can. Ann. Rept., Vol. XVI, 1 04, pp. 302A-31A.
[12]Mines Branch, Dept. of Mines, Bull. No. 7, 1912.

along the bed are listed in Frechette's report on page 8. An average of these is as follows:

Analyses of ore from South Mountain bed:

	Percentage	No. of analyses
Metallic iron	40.80	17
Insoluble matter	24.62	12
Alumina	4.56	5
Lime	2.94	5
Magnesia	0.52	5
Phosphorus	1.56	7
Sulphur	0.016	7

PETROGRAPHY AND CHEMISTRY OF NORTHERN ZONE

Thin sections from the Shell bed show that the ore is composed of detrital quartz grains and calcareous fossil fragments with which occur spherules of green iron silicate, having concentric structure. Crystalline magnetite has developed entirely within these spherules partially replacing the amorphous silicate. A very small amount of hematite is present. The spherules composed of both silicate and magnetite are frequently entirely embedded in a carbonate matrix which is probably calcite.

The green iron silicate resembles chamosite which is a hydrated ferrous aluminous silicate. The bed has a variable thickness, where not disturbed by folding, of from four to six feet. As the name implies it is richly fossiliferous.

The Leckie bed also has an oolitic structure, at some points well, and at others poorly, developed.

Frechette states on page 9 of his report that the ore of the Leckie bed is slightly magnetic. No thin sections of this bed have been examined. Its thickness varies at the Leckie mine from four to nine feet, according to Woodman's report, Plate 24, page 104.

The following averages of chemical analyses are taken from Woodman's report, page 14:

Analyses of ore from Northern Zone:

	Leckie	No. of analyses	Shell	No. of analyses
Fe	49.20	229	44.13	81
SiO_2	15.09	17	16.60	81
Al_2O_3	4.42	9	4.84	6
CaO	4.94	6	6.79	7
MgO	0.67	6	....	..
MnO_2	0.74	8	....	..
P	0.92	55	0.75	25
S	0.077	11	0.098	11

The total iron content of the beds appears to have been originally supplied principally in the form of the green iron silicate, while the sediments were in the process of formation in shallow water along a marine coast. The hematite may also have been an original constituent, but the magnetite appears to be an alteration product due to the intrusion of igneous rocks. Since the beds are primary sediments they are subject to variations from point to point as the character of the sedimentation changed along the coast. There is also a probability that the horizon is continuous between the Leckie mine and westward where a thick mantle of drift has prevented prospecting for a distance of about one mile.

CONCLUSIONS

Oolitic iron ore of sedimentary origin was deposited in Nova Scotia at definite geological horizons in three successive periods of time, i.e., early Ordovician, mid-Silurian and early Devonian.

The ore beds conform to the underlying and overlying strata and contain fossil forms similar to those in the accompanying sediments. The original shell material of fossils, even when composed of thin walls of lime carbonate, is equally as well preserved in the ore as in the rocks.

The iron-bearing minerals are a silicate of iron and alumina, hematite, siderite and magnetite.

The silicate is found in all the ores and is an original constituent of the marine sediments. Hematite is in part an oxidation product from the silicate and together with siderite was deposited while the materials composing the ore still formed a soft sea-bottom deposit. The magnetite has developed as an alteration product from the hematite and silicate due to the metamorphic action of igneous intrusives, after the consolidation and induration of the strata.

Except for the presence of magnetite the ores resemble closely the Wabana iron ore of Newfoundland and the Clinton ores of the Appalachian region in the eastern United States and owe their origin to the precipitation of iron-bearing minerals in shallow marine water.

CONCENTRATION OF CHROMITE.

By L. K. Fletcher.

(Annual Meeting, Montreal, March, 1919)

It may truthfully be said that irregular ore bodies and uncertain market conditions have had more bearing on the milling of chromite in Canada than metallurgical considerations.

The general milling practice on chromite ores has been to grind between 20 and 30 mesh; to concentrate without classification other than a separation of sand slime; to take a concentrate, middling and tailing off the first tables and reconcentrate the middling, without regrinding, on a second set of tables, making on them concentrate and tailing. Slime concentration is comparatively recent.

Chromite concentrate is bought on the basis of 50 per cent chromic oxide content, and grade of concentrate is, at all times, a controlling factor of milling operations. It is therefore sometimes necessary to sacrifice somewhat on extraction to permit a clean concentrate being taken.

Chromite settles rapidly and beds well on the tables, but it is sluggish and does not travel. Only a table having a sharp stroke (kick) will successfully separate it from the serpentine.

This rapid settling and sluggishness is a characteristic which is noticeable through all operations in the chrome mills.

Launders must have at least $1\frac{3}{4}$ inches fall to the foot for 20 mesh ore, and concentrate launders over 2 inches to the foot. Plenty of water must be used to prevent blocking. Chromite will hang back in the ball mill, the elevator boot and in the classifier. In starting a new mill it is several hours before the concentrate appears in quantity on the tables.

Due to this same characteristic, a 2-spigot and overflow classifier tried in one of the mills was not successful. It was found that the table taking the 1st spigot product was overloaded with chromite and a clean concentrate could not be made. The tailing losses were also excessive.

A large quantity of dressing water is used on the tables. At St. Cyr 12 to 15 gals. per minute per table are necessary when treating 82 tons plus a 20 per cent circulating load per 24 hours, on 10 tables.

Experience has shown that the best results are obtained with long tables having a sharp stroke, the length of stroke not being as important. The tables are set flat to keep the ore bed as shallow as possible. Dressing water should commence close to the head end of the table. Raising the concentrate discharge end from ½ to 1 inch is beneficial on some tables.

To date the work done by the No. 3 type Wilfley table used in the old mills has not been improved on.

It is the general practice to reconcentrate the middling product from the first set of tables without regrinding. When crushing to 25 mesh there is very little mineral that is not free from gangue. The middling at St. Cyr is made up of free chromite grains and barren granite. The reconcentration permits a better control of the grade of the concentrate.

The clean chromite from the middling tables is, as a usual thing, several percent lower in grade than that from the first tables.

An extraction of 65 per cent is readily made with the simplest equipment. To increase extraction and maintain the grade of concentrate required by the consumers means a greatly increased capital expenditure for plant. With a plant equipped for fine grinding and sand and slime concentration, an extraction around 80 per cent may be expected.

Ores.—The ore from the Mutual-Belanger lots in the Black Lake district is, by far, the best milling ore found to date in Canada.

The serpentine is soft, easily crushed, free from asbestos and the chromite is evenly disseminated through it in fine grains. There is no excessive sliming of the chromite in grinding and 50 per cent chromic oxide concentrate is obtainable with comparative ease.

Ores from the district around Little Lake St. Francis contain considerable fibre, the chromite occurs in large grains in the disseminated ore and also in massive form, and there is more sliming of the chromite in grinding. 50 per cent chromic oxide concentrate cannot be produced. The range of actual results is from 42 to 45 per cent.

The St. Cyr ore resembles, somewhat, the ore from the St. Francis district. The chromite occurs in large grains, though rarely massive. In grinding it slimes excessively; 48 to 50 per cent chromic oxide concentrate is obtainable.

Mills.—There are in operation, in Quebec, three concentrating mills, only one of which is entirely new since the revival of chrome mining in 1916; the others are stamp mills abandoned in 1909. These have been refitted—one by the Mutual Co. in 1916 and the other by J. V. Belanger, a leaser, in 1917.

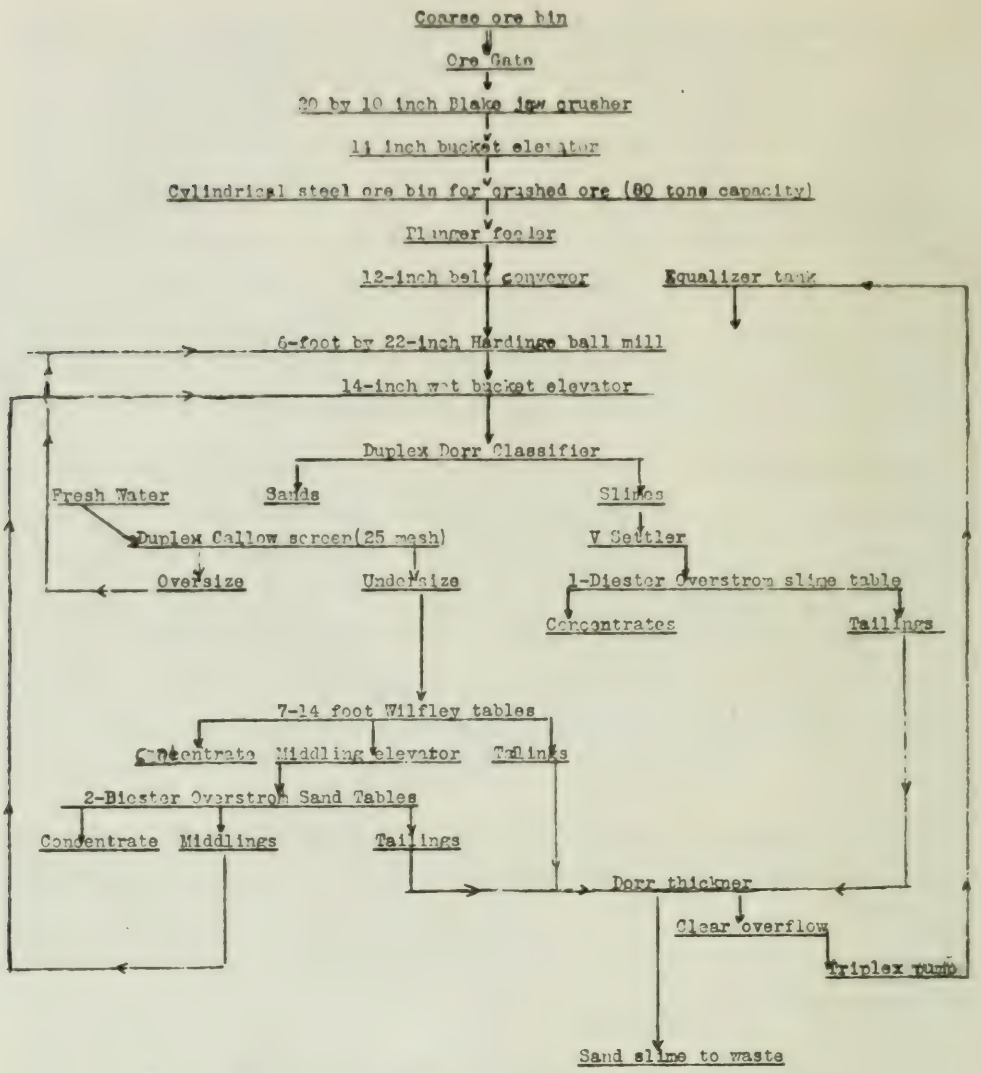
In refitting these mills no changes in the original design, which was the simplest possible gravity concentration, were made.

The Mutual Co.'s mill was operated by them as a customs mill until the spring of 1918, when they took over some of the property tributary to the mill. Since securing mining property they have completely overhauled and re-equipped the milling plant.

The Belanger mill treated ore from property worked by Mr. J. V. Belanger under lease. Later Mr. Belanger acquired property of his own and had planned additions to his milling equipment when the break in the chrome market occurred in the early fall of 1918.

The new mill referred to was built by the Mutual Co. for their St. Francis property, being completed in the fall of 1916. This mill was later sold to the Quebec Asbestos and Chrome Co. and removed by them to their property at St. Cyr.

The skeleton flow sheet No. 1 shows the mill as originally designed.



St. Francis Mill as originally designed.
Flow Sheet No. 1

In re-erecting the mill at St. Cyr, two Diester-Overstrom sand tables and a Diester-Overstrom slime table were added. The Dorr thickener was moved to the foot of the mill to take the entire overflow of slime and sand tailing which go to waste through this thickener, the ratio of water to ore being 2 to 1.

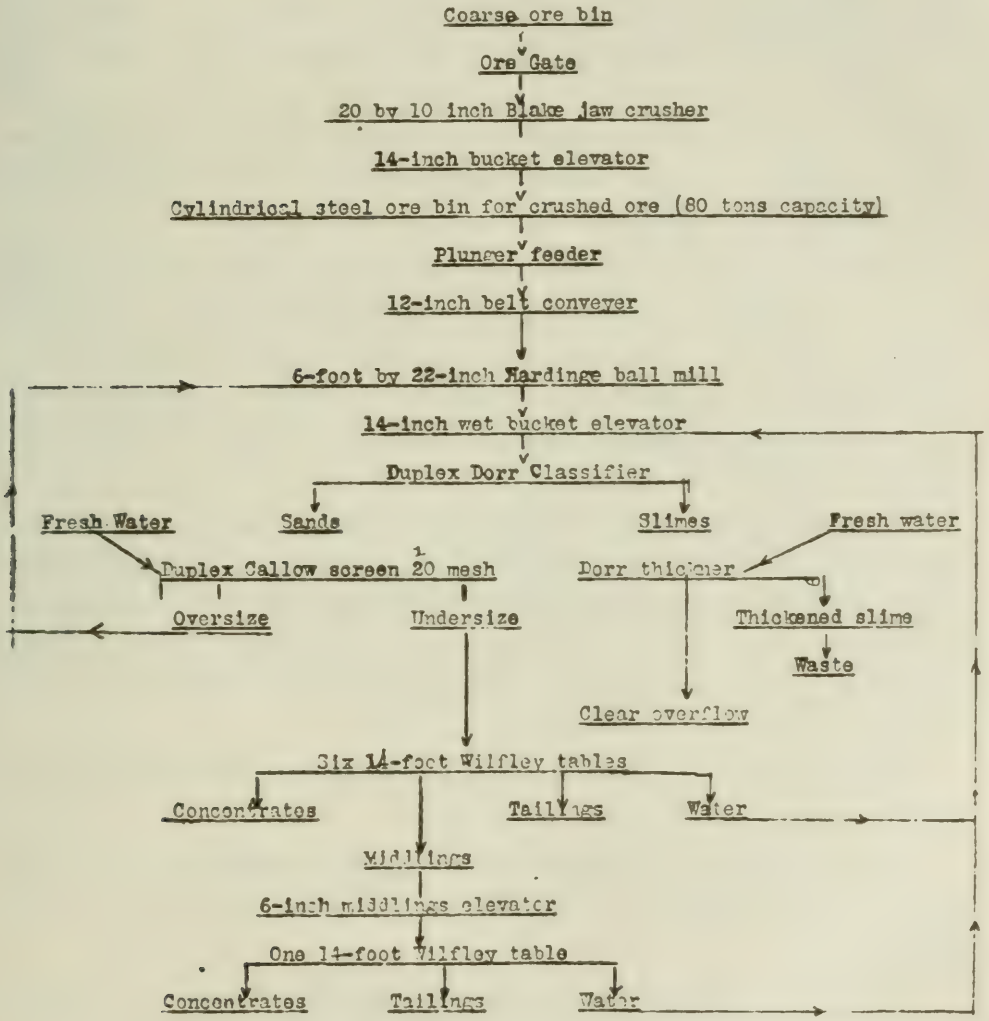
The clear water overflow is returned by a triplex pump to two small equalizer tanks at the head of the mill for re-use as dressing water on the tables.

A V-box settler was built to thicken the overflow from the Dorr classifier for feeding the slime tables.

In the flow sheet No. 2 the mill is shown as re-erected.

The changes in arrangement and the additional equipment were to meet conditions at St. Cyr which differed from those at Black Lake.

1st.—The ore to be treated is much richer in chromite and the short No. 6 Wilfley tables had not been entirely satisfactory even on low grade ore.



St. Francis Mill, as re-erected at St. Cyr.
Flow Sheet No. 2

2nd.—A water shortage during the summer and winter seasons was anticipated, making water saving important.

3rd.—With richer ore, slime concentration became necessary.

The ore treated to date comes in part from underground working; the proportion of dump ore to mine ore has varied from two-thirds dump ore when the mill started to two-thirds mine ore at the present time.

Unfortunately the dumps had not been kept free from waste rock coming from the sides of the pits. This waste is made up of serpentine containing asbestos fibre and granite (or vesuvianite). To the presence of this asbestos and granite may be attributed practically all the difficulties encountered in milling St. Cyr ore. These should disappear with the exhaustion of the dump material, as the ore from the mine contains little or no granite and asbestos.

As the specific gravity of a large part of the granite is around 3.5 and the specific gravity of chromite concentrate only a trifle over 4 (tests running from 4.1 to 4.3) the granite was concentrated into the middling product of the tables, building up a circulating load of granite which eventually found its way into the concentrate.

To provide an outlet for this granite the Diester-Overstroms were arranged to cut middling either to waste or back to circulation. When cutting the middling to waste the loss from these tables was heavy, but as the grade of concentrate from the whole mill was raised several points, the change was warranted.

The concentration of the slime has proved a difficult problem, due to asbestos.

The asbestos fibre is held in suspension and flows over with the slime from the Dorr classifier, very little going into the sand discharge.

Chromite grains become entrapped and are carried into the slimes by the fibre. Grains of chromite as coarse as plus 30 mesh have been noted in the slime overflow.

On reaching the settler the asbestos settles rapidly, and a large part goes into the slime table feed.

On the table the asbestos forms a coating, about the consistency of freshly made putty, which, if not swept off at frequent intervals, will build up until it completely covers the riffles.

Every effort, short of installing more equipment, has been made to overcome this asbestos trouble, but with only partial success to date.

Keeping the percentage of solids in the slime low (4 to 5 per cent) and using a high pressure spray pipe in the classifier near the slime overflow liberates trapped, coarse grains of chromite, but it has been found impossible to keep the asbestos out of the table feed.

Shortly after the St. Cyr mill commenced operation the market for chrome was reported over-stocked. As the company had contracts for concentrate cancellable on Jan. 1st, 1919, the tonnage and grade of this concentrate became of the utmost importance and extraction a secondary consideration.

Accordingly, more mine ore and less dump ore was treated and the mill was pushed to maximum capacity. It was then found that on the rich ore the Wilfley tables would not handle the tonnage that the ball-mill could grind. The flow was therefore changed, the undersize from the Callow screen being distributed to the seven Wilfleys and the two sand Diester-Overstroms, and the middling from Wilfleys being returned to circulation or cut to waste.

OCCURRENCES OF CHROME IRON ORE

By James G. Ross

(Annual Meeting, Montreal, March, 1919)

Government reports showing chrome production usually list the following countries: Canada, England, British Africa, French Oceania, Portugese South Africa, Turkey in Asia and the United States of America. To these should now be added Cuba and Brazil.

Occurrences in Canada

Quebec.—Chromite occurs in the same serpentine belt in southeastern Quebec as does asbestos. The two minerals, however, are rarely associated. In one of the asbestos pits of the Black Lake Asbestos & Chrome Co., a body of chrome ore was found from which several carloads of high-grade crude ore were shipped. In the pits worked for chromite, there is seldom found asbestos in commercial quantities. The belt extends as far east as the Gaspé peninsula, and the most westerly working is at St. Cyr. Coleraine county is the centre of the chrome industry, shipments being made from Coleraine and Black Lake stations on the Quebec Central Ry. Production was at a standstill from 1909 to 1915. Lack of shipping to bring foreign ores to the United States caused the price of ore to rise to a figure which induced operators to reopen old workings and prospect for new deposits. Operations were started at the two concentrating mills already in existence, and two new mills were erected, one at Caribou Lake and one at St. Cyr. On three properties, shafts have recently been sunk and underground mining commenced. With this development, it is hoped that producers in the Quebec district will be able to market their product in competition with producers elsewhere, even when prices decline to the pre-war basis.

British Columbia.—A chromite deposit is being developed near Cascade, Grand Forks mining division. Small deposits also occur in the Tulameen district.

Newfoundland.—Although not shipping any ore at present, records show that some 3,000 tons were produced up to 1897 from a deposit at Bluff head, Port au Port bay. The ore was said to range from 39 to 50 per cent Cr_2O_3, and one body was stated to be 97 feet long and 45 feet wide.

OCCURRENCES IN THE UNITED STATES

California.—Under war conditions, many old workings were reopened and new deposits discovered by prospectors. Although a considerable tonnage of chromite came on the market, no districts are likely to provide a large production on a pre-war basis. One of the most interesting developments was the installation of concentrating mills to recover chromite from beach sands and from tailings at old gold workings. In addition to the chromite, there is said to be recovered magnetite, garnets, and zirconium, as well as titanium, gold and platinum. In this state alone, no fewer than twenty-five counties contributed to the chromite production in 1918; two hundred and forty-five companies and individuals being listed as operating. The production came from two main belts, one along the Coast range from San Luis, Obispo Co., to the Oregon line, and the other in the Sierra Nevada, from Tulane Co. to Plumas Co. In these districts the lenses, which occur in basic igneous rocks (such as peridotite and pyroxenite, and in serpentine which has been derived by alteration of such basic rocks) are said to be small, relatively few of them yielding individually over 100 tons. One notable exception, however, was a deposit on Little Castle creek, near Dunsmuir, from which upwards of 15,000 tons were taken. The orebodies of the northwestern part of the state appear to be larger in size than in other parts. Californian ores are, as a rule, higher in silica than Canadian ores. Other states reporting production in 1918 were Oregon, Maryland, Wyoming and Washington.

Maryland.—In 1827 chromite was discovered in Hartford Co. The Reed mine alone produced over 100,000 tons. A remarkable fact about this deposit was that ore was struck at a depth of 8 feet below the surface, there being no outcrop. In the

same region near Baltimore, the mineral was found in the form of sand which was then concentrated.

Pennsylvania.—Up to 1880, the Wood mine in Lancaster Co. produced 95,000 tons. This property was developed as a mine with regular levels to a depth of 700 feet.

Chromite has also been found in Virginia, North Carolina, and Vermont, but has not been mined to any extent. In Alaska a lode deposit is reported to have been found near Port Chatham on Kanai peninsula.

OCCURRENCES IN OTHER COUNTRIES

South Africa.—While shipments of chromite have been reported from Rhodesia, Cape Town, and Portuguese East Africa, the actual centre of production is at Selukwe in Rhodesia, the ports of shipment being Cape Town, and Beira in Portuguese East Africa. A deposit known for years as Iron Hill was, in 1908, found to be chrome ore of high grade, and since then a large part of the world's requirements have been supplied from this property. Quarrying is cheap, wages paid the black boys being £1 a month and 'scoff' (board). The property is situated in a high rolling country not far from some gold mines. The climate is favourable for economic working throughout the year. The freight haul to Beira, the nearest port, is 736 miles. Loading at the port is done by lighter in an open roadstead.

According to "Commerce Reports" a deposit of high-grade chrome ore has been discovered in the Umvukwes range in Rhodesia. Surveys are said to have indicated the occurrence of two million tons of ore. In addition to the lode there is reported to be a large alluvial deposit covering 1,500 acres. To develop these, a railway will be required to connect with the main line at Banket Junction, 30 miles distant.

New Caledonia.—This French colony is situated about 900 miles east of Australia. Chromite and garnierite are the principal minerals mined. On the eastern slope of the island near the northern end, is the Tiebaghi mine, which has been a steady

producer of high-grade ore for many years. The ore is quarried from a hillside deposit and transported, by an aerial tramway, seven miles to Pagoumene, a harbour on the western side of the island. The tramway not only requires no power for its operation, but develops sufficient power to provide the requirements in this respect for lighting and for running a machine-shop plant. Labour, principally Japanese and Javanese, is cheap.

Asia Minor.—Brusa, the shipping port, is usually credited with being the producing centre. As a matter of fact, the deposits are situated near Mount Olympus in the Dagardhi mountains. The ore is packed out on camels and asses, a trip occupying several days. The workings may also be reached by taking the Angora Railway from Hiddar Pasha, opposite Constantinople, to Eskesher, the junction with the Koniah line. A three days' ride on horseback from Kutiahi, a station on this line, over country tracks and a range of mountains, brings one to the deposits. Naturally, no ore has been received from Asia Minor during the past four years.

Russia.—Prior to the war a large production of chromite was derived from deposits in the Ural mountains, but it may be some time before conditions become settled enough to admit of the supply from this source again becoming a market factor.

Greece.—Deposits near the port of Volo are associated with basic rocks and limestone.

Macedonia.—Shipments are reported from the port of Salonika, but the country has been too unsettled for years to permit of an investigation of the deposits.

Austria.—Chromite is reported as occurring at Kraubat in Styria.

India.—An increasing production from Baluchistan is shown.

Australia.—Although chromite occurs in the Mooney-Mooney range near Gobaralong, in the Gundagai district in New South Wales, there is no production of importance.

Production credited to Australia probably represents transhipments from New Caledonia.

New Zealand.—Chromite deposits were at one time worked on Mount Dun, back of the port of Pictou on the South Island. These, however, have been idle since 1866.

Other Countries.—Norway, Cuba, and Brazil are stated to produce some ore. In Cuba, it is associated with the iron ores.

When times again become normal it is probable that production of chromite will be derived mainly from Rhodesia, New Caledonia, Asia Minor and Russia, and to a smaller extent from California and Canada. Possibly some production may also be made by Brazil and Cuba.

THE HIDDEN CREEK MINE AND ITS OPERATIONS

By E. E. Campbell

(Annual Meeting, Montreal, March, 1919)

The Hidden Creek mine of Anyox is owned by the Granby Consolidated Mining, Smelting and Power Co., Limited, of Vancouver, B.C., and produces about two-thirds of the copper made by that Company, amounting to about 30,000,000 pounds annually.

The property is situated seven hundred miles north of Vancouver, and a hundred miles north of Prince Rupert, on Granby bay, which forms a landlocked harbour four miles long and one mile wide, opening into the west side of Observatory inlet. The harbour is amply suitable for ocean-going ships of the largest tonnage. Wharf facilities are adequate for handling up to 50,000 tons of material per month from outside, which in general consists of ore from custom shippers, ore from outside

A view of portion of water front at Anyox. The smelter is shown in background.

General view of Hidden Creek mine.—From l ft. to right: smelter, railway, 150 tunnel entrance, crusher bins and track to 385 tunnel, 530 tunnel entrance and outcrop of No. 1 orebody.

company properties, quartz flux, limestone flux, coke, lumber, and general mining and town supplies. The wharf frontage measures approximately 2,000 feet. It is built on creosoted piling, and is equipped with the necessary travelling unloading appliances for ore, coke, and flux with a 50-ton derrick for handling heavy machinery, and with a double track railway connecting with the main railway to the smelter and the mine.

At the beach all available building ground between the harbour entrance and smelter is occupied by the living quarters of employees, together with the other necessary buildings, such as offices, stores, hotels, boarding houses, recreation hall, churches, schools, etc. Bunkhouses and rooming-houses for the single men, and three hundred cottages provide accommodation for a thousand employees.

The smelter buildings are situated on the west side of Falls creek, at an elevation of about a hundred feet above sea level, thus giving a good grade for the granulated slag which is discharged into the bay. The hydro-electrical and hydro-mechanical power plant

is placed on the south side of Falls creek just above high tide, while the auxiliary steam plant is situated on the opposite side.

The Hidden Creek mine is about one and a half miles north in a direct line from the smelter site, and here living quarters

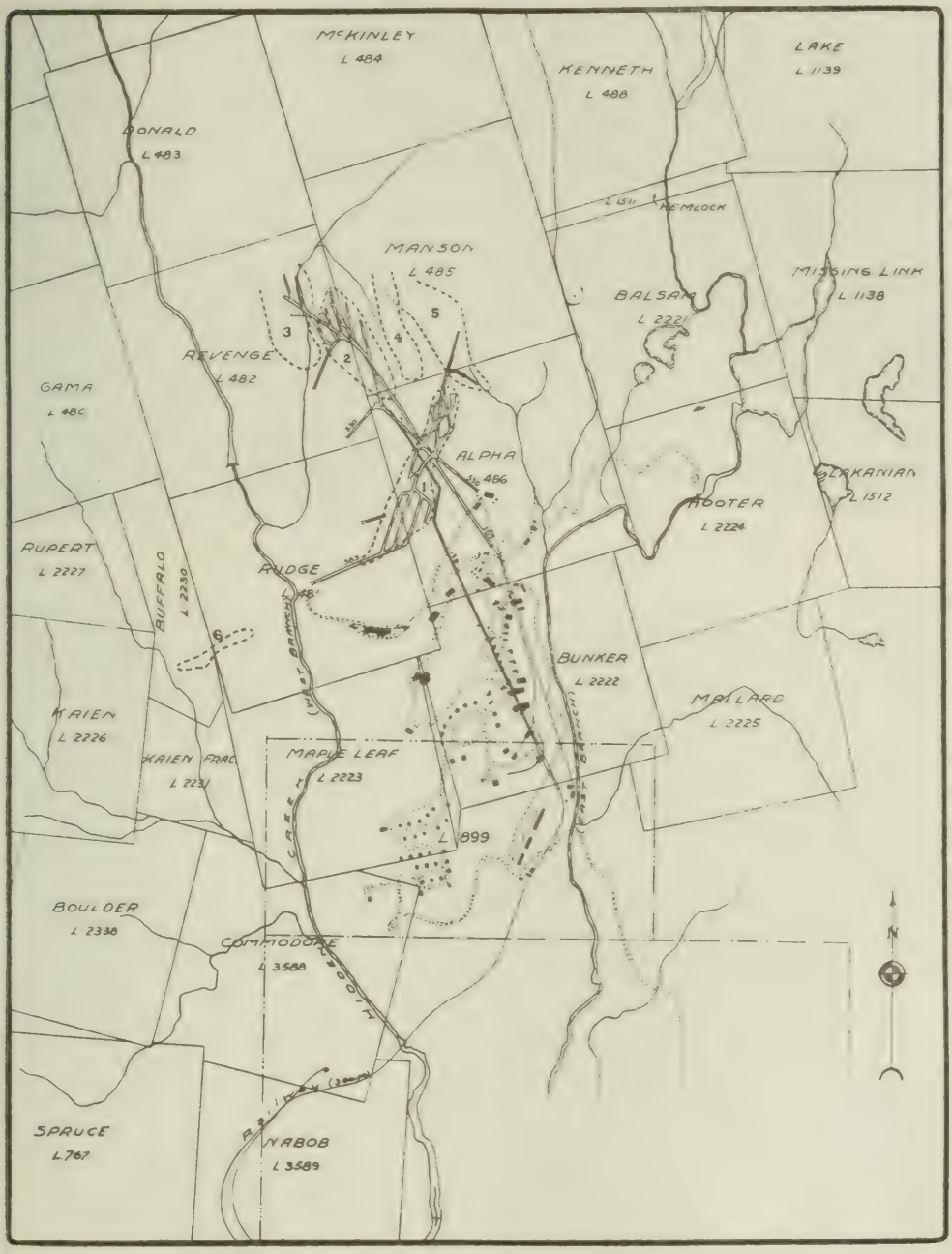


Fig. 1.—Plan showing mines, town, roads, outline of orebodies, underground workings, etc.

have been provided for the mine employees. The bunkhouse accommodation is sufficient for about three hundred and fifty men; and seventy-five houses for families have been built. Other buildings at the mine consist of mess-house, mine dry-house, mine club and mess-house for the office staff, store, office, machine shop, carpenter shop, and all other necessary buildings required in mine operating.

The Granby mineral claim holdings at Anyox, consist of one hundred and fifty-five crown granted mineral claims and fractions, amounting to 6,570 acres. This area occupies a large proportion of the low-lying ground surrounding Granby bay, and beyond this the ground in general rises quite rapidly to elevations up to 6,000 feet. The highest elevation attained on the Mine hill approximates 1,000 feet above sea level.

The geology of the area in the vicinity of Anyox, is, in general, simple, while the detail geological structures are more or less obscured by alterations caused by mineralizing agencies.

The rocks observed in the area adjacent to the mine consist of a series of sedimentaries, ranging from fine-grained argillites to limestones in contact with green schist. The above rocks which constitute the country rocks in which the orebodies occur, have been cut by a great number of dykes, from a few inches up to a hundred and more feet wide, with chemical compositions varying as greatly as their width.

Outside of the Hidden Creek area, these ore-bearing formations have been intruded by granite which flanks the area on the south, west and east, the distance from the mine being from two to five miles in the different directions.

The contact between the green schist and the argillites is marked by a wide band of silicification, which is an alteration in a minor degree of the greenstone, and in a far greater degree of the sedimentary rocks. This zone varies from two hundred to four hundred feet in width, and contains some of the most valuable orebodies occurring on the property. The orebodies in this zone of silicification are made up largely of massive sulphides

North end of glory hole No. 1 orebody.

Machine benching in a glory hole. The rock shown in the upper left-hand corner is coarse ore.

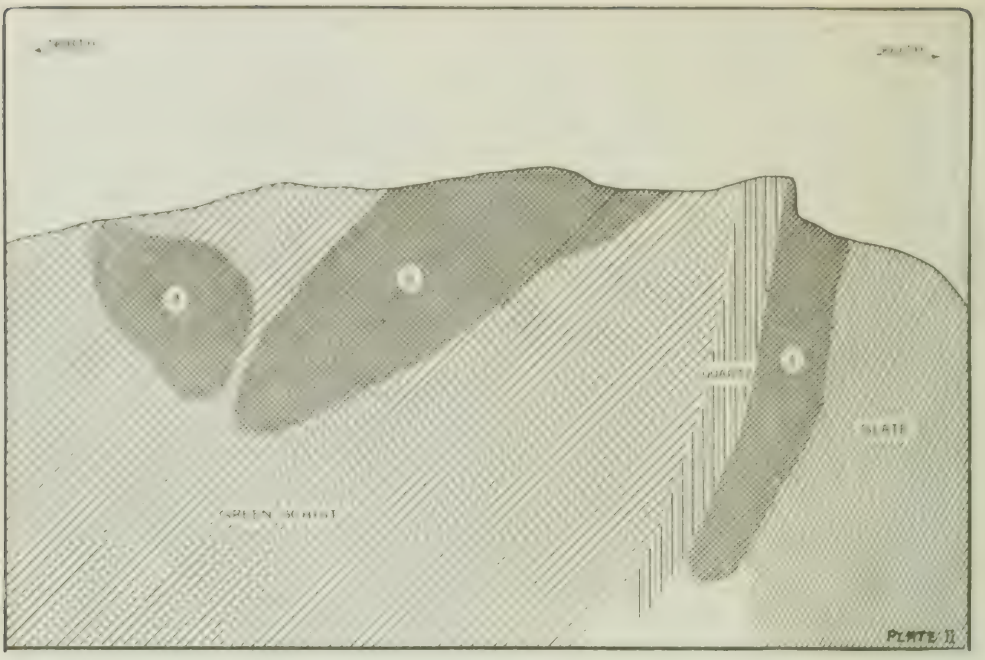


Fig. 2.—North-south vertical section through Nos. 1, 2 and 3 orebodies.

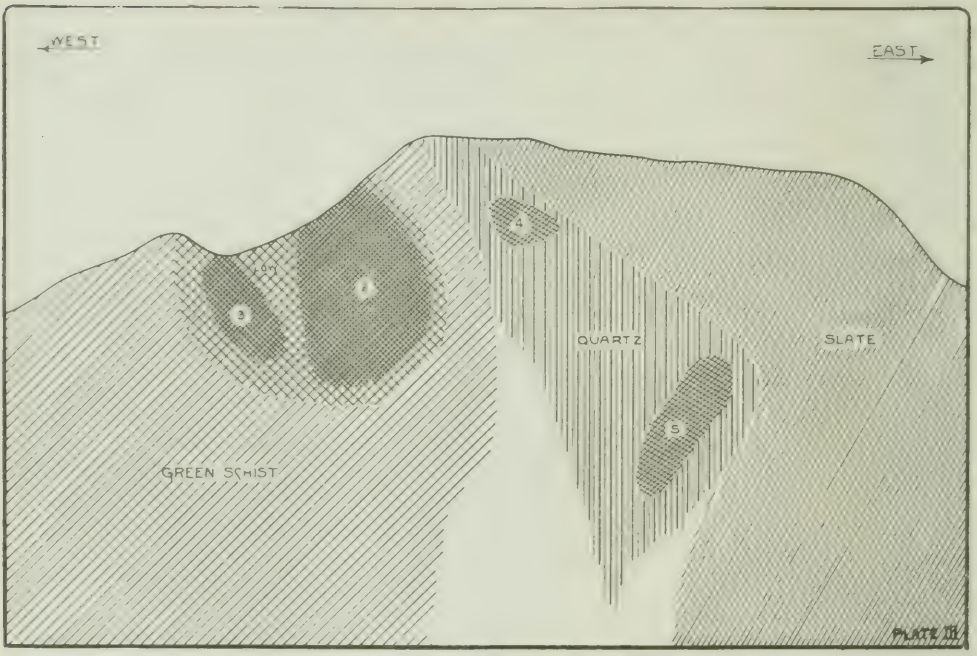


Fig. 3.—East-west vertical section through Nos. 2, 3, 4 and 5 orebodies.

of iron and copper, and a small percentage of zinc. Another very valuable occurrence of ore is that found along shear zones in the green schist. The ore consists of disseminated sulphides in a schist gangue and is much lower in iron and sulphur and much higher in silicates or combined silica than the ore in the contact zone.

The Hidden Creek ore carries very low values in gold and silver, and up to about a year ago the average amounted to about 30c per ton combined values. Since the development of No. 5 orebody a marked increase has been observed in the precious metal contents, raising the total to almost 50c per ton.

In the silicified zone three orebodies have been found and called Nos. 1, 4 and 5. Of these orebodies No. 1 is by far the largest. It has a proven length of 1,500 feet, and a continuous outcrop of 1,000 feet. Its width varies from 100 to 250 feet, and diamond drilling has shown that it extends to a depth of more than 1,000 feet below the outcrop. Throughout this vertical distance there is no evidence of a change in values, the average percentage of copper being as high at a depth of 1,000 feet as at the surface.

The general analysis of the orebody as determined by underground development and diamond drilling, is:

Cu.	Ins.	SiO_2	Fe.	CaO	S.	Al_2O_3	MgO.
2.37	25.8	22.4	29.6	4.7	30.0	5.1	1.3

Nos. 4 and 5 orebodies do not outcrop and were discovered by diamond drilling. No. 4 is the lowest grade of all the orebodies, but it has the highest iron and lime and the lowest insoluble content of any of the orebodies, which makes it very valuable for its fluxing qualities. Outside of the portions estimated as ore, are large masses carrying low copper values with a sulphur content running from 40 to 50 per cent. A number of shipments of this have been made during the past year to be used for acid manufacture.

The analysis of the shipping ore in this body is as follows:

Cu.	Ins.	SiO_2	Fe.	CaO	S.	Al_2O_3	MgO.
1.52	12.2	9.2	37.0	9.8	30.5	3.0	0.8

No. 5 orebody shows a much higher copper content than any of the other orebodies, and carries gold and silver values exceeding $1.00 per ton. It is also low in insoluble and high in iron and lime, so rendering it an easy smelting ore.

The average analysis of this ore is:

Cu.	Ins.	SiO_2	Fe.	CaO.	S.	Al_2O_3	MgO.
3.02	16.1	14.8	34.0	5.9	33.3	1.6	0.0

These orebodies as may be seen by their average analyses are essentially heavy sulphides; however in many cases the sulphides fade gradually into the silicious walls, thus forming areas of disseminated sulphide ore with a gangue having a large percentage of free silica. This silicious material, containing from 0.5 to 2.0 per cent copper is mined for flux, and is especially desirable for the convertors, where clean quartz produces too high a temperature for proper work.

Orebodies 2 and 3 occur in the schist and contain a schist gangue; consequently they are far more refractory, and present more metallurgical difficulties than does the ore occurring in the silicified area.

The analyses of these orebodies are as follows:

Cu.	Ins.	SiO_2	Fe.	CaO	S.	Al_2O_3	MgO.
2.24	40.7	33.2	25.6	3.0	18.0	10.8	4.0
1.82	48.8	40.8	21.6	1.5	7.9	11.5	6.6

In order to smelt this schistose ore it is necessary to mix it with a certain proportion of sulphide ore from the silicious area, and for that reason two general classes of ore are mined and shipped separately. None of the orebodies shows oxidation.

The sulphides present are chalcopyrite, pyrite and pyrrhotite.

The Hidden Creek mine is operated from three different tunnels situated at elevations of 150 feet, 385 feet and 530 feet, respectively, above sea level, and these elevations are used in naming the tunnels.

Tunnel 150, which is the lowest, is driven on a level with the railway which connects the mine and the smelter, and from this point the ore from the crushers above is drawn into the railway-cars for shipment to the smelter. During the past year this tunnel, which heretofore was used as a shipping tunnel only, has been extended to the orebodies which are being developed at that level.

Tunnel 385 is the main shipping tunnel for mine-run ore, and to this tunnel all of the ore mined above is conducted, either through pockets extending to the level above, or through chutes drawing from stopes directly above the level. The coarse ore is loaded into the mine cars and transferred to the crusher station. After crushing, it is dropped into pockets extending to the 150-ft. level.

Tunnel 530 being about on the level of the main stoping operations of the mine, is used chiefly for handling steel and other supplies, and as an entrance to stopes. A small amount of ore from No. 1 orebody is transferred into pockets, but the tunnel is fast coming into disuse excepting as a manway.

Two other tunnels on levels 630 and 700 were driven during the early stages of mine development. These are used as manways into stopes and glory holes, and for ventilation.

The total mine development to date, including drifting and raising, amounts to 37,178 feet, while diamond drilling amounts to 95,835 feet.

Two distinct mining methods are in use at the present time. These are an open stope or drilling method, and a shrinkage stoping method. The open stope mining as carried on by the Granby Company at Anyox consists, essentially, of starting a

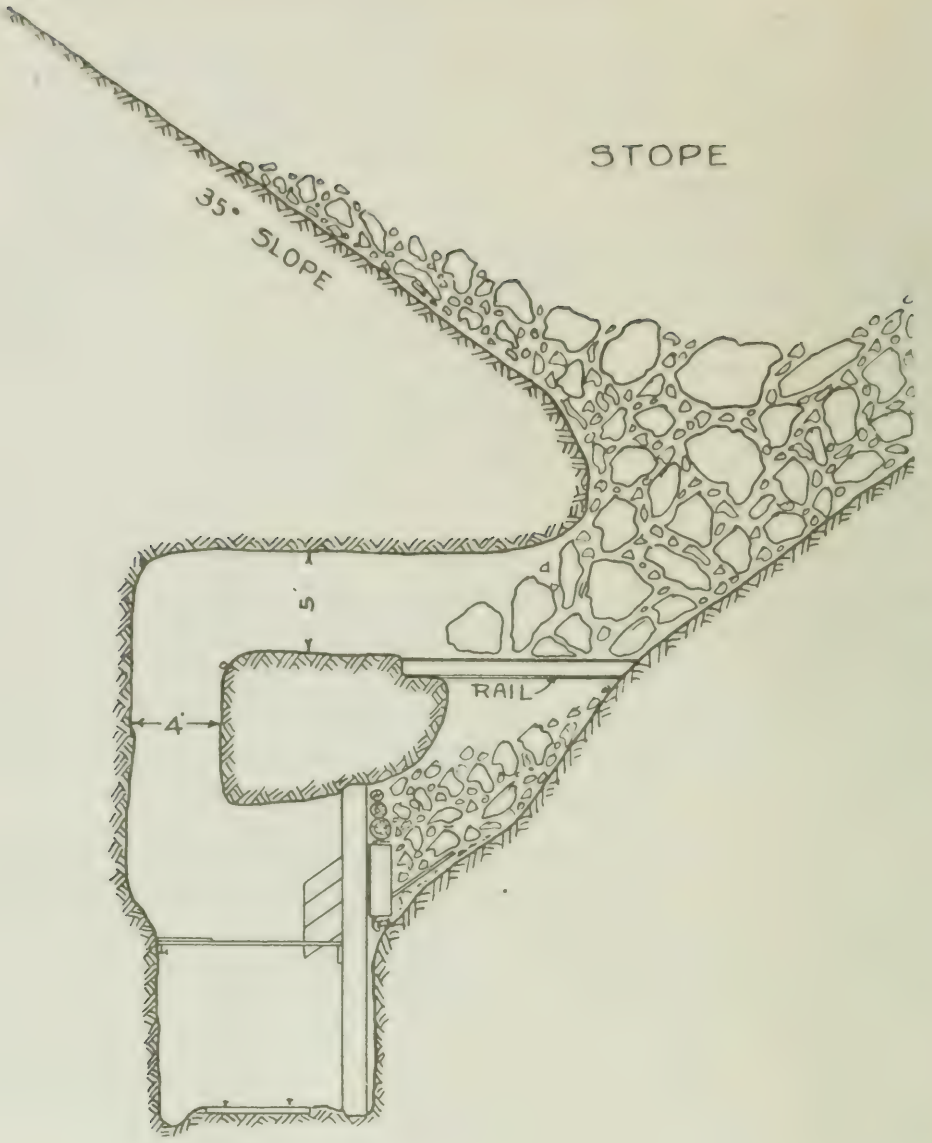


Fig. 4.—Section showing stope, chute, manway and grizzly.

raise (and ultimately a series of them) into the orebody, then widening the raise as it advances upwards, by working around the sides, keeping the slope of the floor steep enough for the broken muck to run into the chutes. This broken ore is always available for drawing as it plays no part in subsequent mining. This system works admirably in strong ground where the overburden of rock

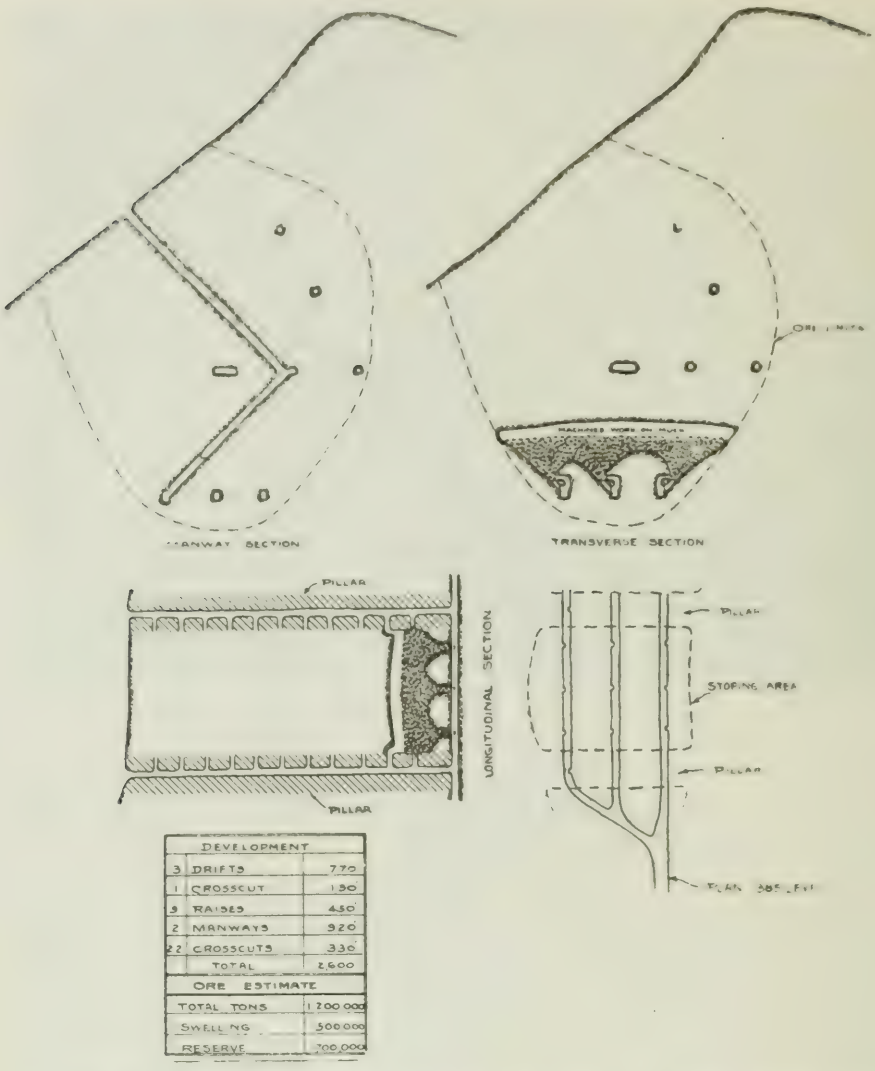
Stoping at Hidden Creek mine.

is not too heavy, or where the orebody lies in such a position that pillars may be left to support the roof.

At the Hidden Creek mine a number of stopes were worked upwards, finally uniting into one and being continued to the surface, formed large openings called glory holes. When broken to the surface, benching work and side swiping is done, the broken ore falling down through the old stopes into the raises at the bottom.

The shrinkage stoping system which is being inaugurated in some parts of the mine, is applied as follows:

Vertical manway pillars are left across the full width of the orebody at suitable distances apart, which distance is the stope width. Sufficient raises containing chutes are driven into the bottom of the stope, the tops of which are widened out in the same manner as in the open stope method, until all of the raises are connected. This results in the complete cutting away of the



DEVELOPMENT		
3	DRIFTS	770
1	CROSSCUT	130
3	RAISES	450
2	MANWAYS	920
22	CROSSCUTS	330
	TOTAL	2,600

ORE ESTIMATE	
TOTAL TONS	1,200,000
SWELLING	500,000
RESERVE	700,000

Fig. 5.—Plan and two sections of one large shrinkage stope; also section through manway.

bottom of the stope. Back stoping is then started, the back being reached by working on top of the broken ore, sufficient ore being drawn out to keep the stope from blocking. Crosscuts are driven from the pillar manways into the stope at about 30-ft. intervals, as the stoping advances upwards. These many crosscuts serve to ventilate the stope as well as being a means of entrance.

The broken ore from the mine is handled over a 3-ft.

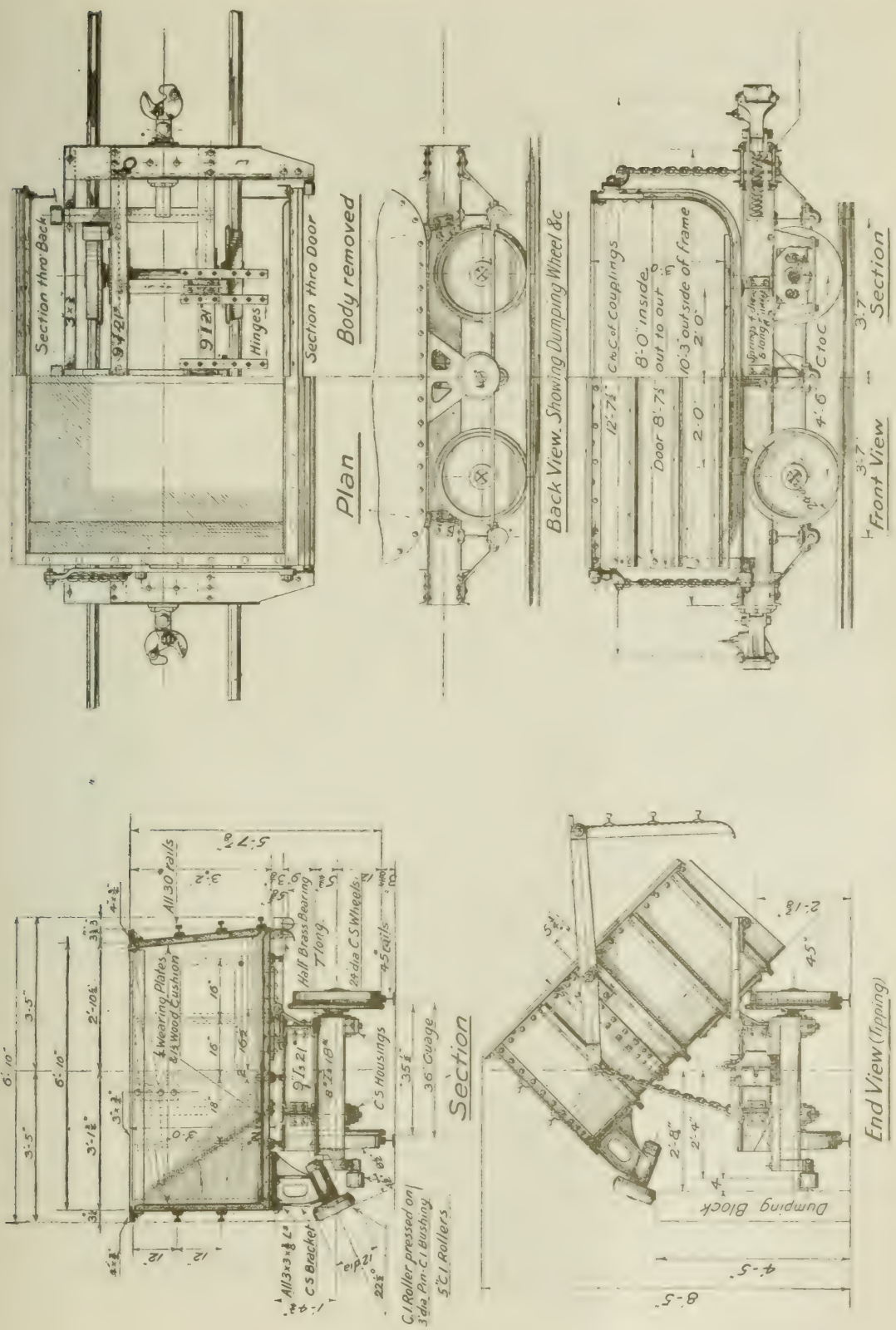


Fig. 6—Granby automatic dump car

gauge track, in cars of the Granby automatic dumping type, holding 130 cubic feet each. Trains of these cars are hauled by 12-ton Westinghouse electric locomotives of the bar-frame type, using a trolley current of 500 volts.

The ore is crushed in two crushing plants, either of which can easily crush the maximum output. Crusher No. 1 is installed underground, intermediate between the 150- and 385-ft. levels, the space above the crusher being used for coarse ore pockets and the space below for crushed ore pockets. The machine is a Bacon-Farrell crusher with cast iron frame, and has a jaw opening measuring 36 x 42 inches. The crusher is driven by a 150 H.P. Westinghouse A.C. motor, 2,000 volts, connected to a line shaft, which is double belted to the crusher. Crusher No. 2 is of the same type as No. 1, has a cast steel sectional frame and a jaw opening 30 x 42 inches, and has the same power arrangement as the No. 1 plant. This crusher is installed on the surface below two coarse ore bins of a capacity of 250 tons each. The crushed ore drops into pockets extending to the 150-ft. level, from which it is drawn into the smelter train cars.

The cars used on the railway to the smelter are hopper bottom having a capacity of 25 tons each, running on a 3-ft. gauge track, using 56 lb. rails. The locomotive is a Westinghouse-Baldwin type machine weighing 42 tons, with a trolley current of 500 volts.

Two different types of rock drills are used in mining, viz., piston machines and hammer drills. The piston machines are manufactured by Holman Bros., Cornwall, England, and the hammer drills by the Denver Rock Drill Co.

The compressed air used is produced in the power plants at the Beach, and is conducted to the mine through two pipe lines, one eight-inch and the other six-inch, the length of lines being 8,000 feet. Two compressors are used, one a Nordberg, 4,000 cubic feet capacity, direct connected to a Pelton Doble water wheel, and the other an Ingersoll-Rand motor driven machine having a capacity of 2,500 cu. ft. of free air per minute. A 3,500 cu. ft. De Laval turbo compressor, either

steam or motor driven, has recently been installed to provide for the increased consumption of air, incident to many new developments at mine and smelter.

The necessity of meeting the steadily increasing cost of labour and supplies, due to war conditions, presents many problems to the mine operator.

At the Hidden Creek mine many changes were made in details of work, numerous economies were carried out in the use of mining materials, and improved equipment was installed in order to meet the continually increasing prices.

The minor changes made during the latter part of 1915 and the first part of 1916 may be summarized as follows:

An accurate record was kept of all explosives used, and the consistent use of tamping in all first blasting was introduced. Specially picked men, receiving bosses' pay, were detailed to watch the powder consumption, and to instruct inexperienced men in its proper use. Extensive experiments were made with the different kinds of rock drills, as well as with the different types of drill bits, which latter proved an important factor in increased drilling speed. A ban was placed on 'bulldozing' as far as possible, and all boulders were drilled that could be reached with safety. Centrally located pockets, about fifteen feet square, were driven from the 385-ft. level or shipping tunnel, to embrace a large area of stoping ground above the 530-ft. level, which eliminated the transfer of broken ore on this level. All pocket chutes were increased in width from 3′ 2″ to 5′ 8″, and a new haulage system was installed on the 385-ft. level using cars of 130 cubic feet capacity with 12-ton locomotives, instead of the former equipment of 75 cu. ft. cars and 6-ton locomotives.

While a marked improvement resulted from these efforts, the real operating problem was not completely solved, which is the handling of the broken ore from the first blasting in the stopes and glory holes, through the mine to the crusher plant.

The mineralized schist making up No. 2 and No. 3 orebodies drills fairly well and often breaks readily in very large

masses. This is due to slips, seams and occasional small dykes cutting through the orebody. After these natural partings are broken, the remaining large pieces are most resistant to blasting. To illustrate: A few months ago a piece of ground measuring 60′ x 30′ x 20′, containing several thousand tons, was blasted down in the glory hole. It rolled at least 150 feet without breaking, and it required several days' drilling to break it fine enough to let into the pocket.

When the first central pocket was driven from the 385-ft. level to the upper workings, it was equipped with a manway at the lower end which entered the pocket at a point about 25 feet above the chute. Here a big opening was made to make room for drilling large pieces before they reached the chute. Another entrance was made at a point where the pocket passes the 530-ft. level. It was soon found that many large pieces escaped from the glory holes and stopes into the pocket before they could be drilled. These frequently blocked the pocket 100 feet or more down. Dislodging these rocks entailed a great deal of danger to the men doing the work, as well as consuming an excessive amount of powder, as it was impossible to use a drill in such a position, and 'bulldozing' had to be resorted to. When the rock blocking the pocket was exposed from the top the usual procedure was to place the powder in a sack, light the fuse and lower the sack on to the rock with a rope. If this rock is covered up, as often happens, the only alternative is to use ladders to climb up from the nearest manway below, and place the charge to the best advantage possible. There have been times when several cases of powder were used to clear a jam of boulders in one of these pockets.

Thus at this stage, the saving in tramming expected from these pockets proved more an expense than an economy. As soon as the work could be done a manway was driven up beside the pocket from the 530-ft. level to the top, with openings into the pocket at intervals of about 30 feet. Equipped thus, it was much easier to reach a blockade, but the amount of powder required to keep the pocket open was still excessive, and many pieces passing readily through the pocket were too large to go through the chute.

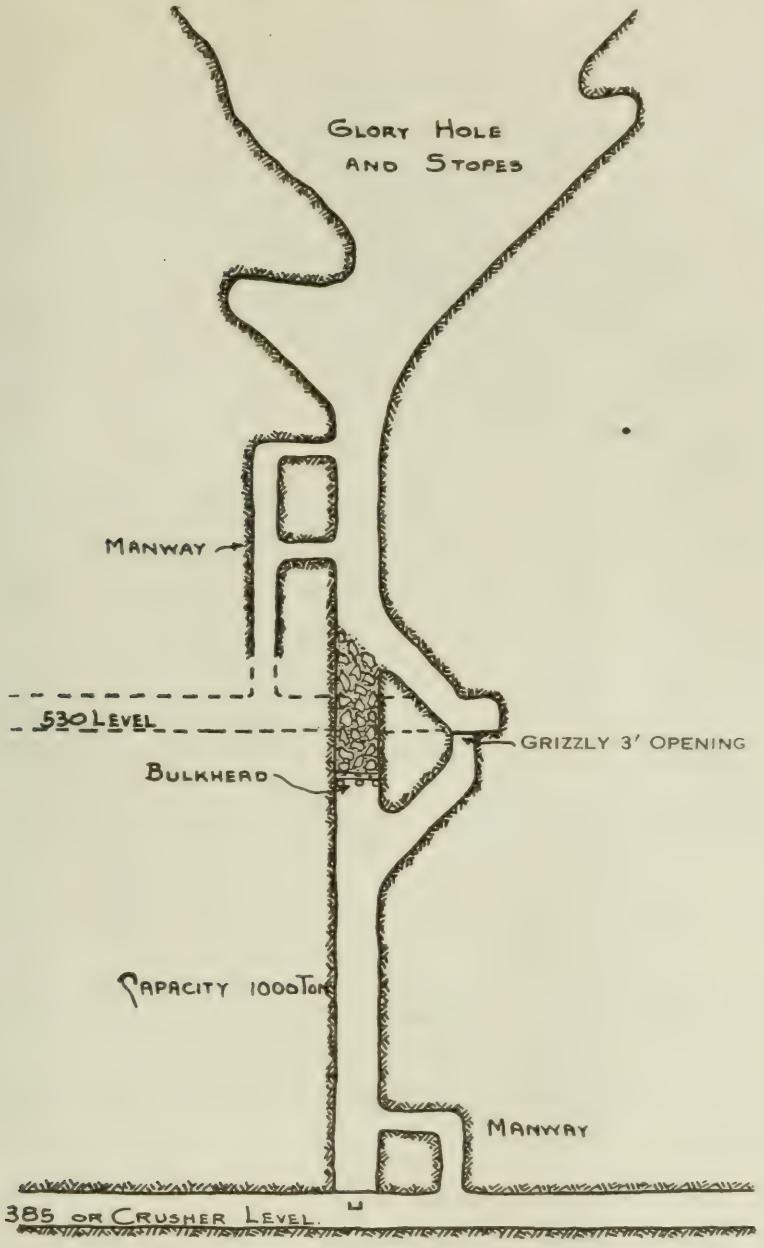


Fig. 7.—Section showing grizzly arrangements in raises.

These frequently had to be 'bulldozed' at or near the chute, making big repair costs and wasting much powder.

The next experiment was to pass the rock going into a pocket over a grizzly. At first the idea of having pieces of rock weighing 50 tons and more rolling on to a grizzly did not seem practic-

able. The grizzly installation was made at the 530-ft level. A bulkhead was put in the pocket below the tunnel level. From a point below this bulkhead a raise was driven breaking into the bottom of the tunnel, and grizzly rails were fitted into this opening. A second raise was then driven from above the grizzly back into the pocket. This latter raise diverted the ore out of the pocket on to the grizzly, and the lower raise returned it into the pocket again below the bulkhead. The pocket above this grizzly was further increased in size to lessen the possibility of blocking.

The grizzly rails are 8 feet long and they are placed 3 feet apart. Although much difficulty was experienced in procuring rails that would withstand such violent service, and the cost of renewals seems extravagant, the reduction in explosives and chute repairs, together with the advantage of uninterrupted operations, more than counterbalance any of the disadvantages. The rails now used are made up of two 125-lb. track rails bolted strongly together, and each is re-enforced with a 1″ x 5″ flat iron strip riveted on the bottom. The temper is partially drawn from these rails before using, as they are very brittle and break readily. Under ordinary conditions these rails last from one to two weeks. It is probable that a more suitable rail can be procured when the steel market becomes normal.

The attached sheet shows annual cost distribution, tonnage of ore shipped, tons produced per operation shift, and tons produced per machine shift, from the beginning of operations in 1914 up to January the 1st, 1919.

The twelve month periods over which these figures apply end on June the 30th of each year. For this reason the last column is a record of six months' operations only, from July the 1st, 1918, to January the 1st, 1919. Continuous operations did not commence until 1914, consequently the cost figures obtained in 1913-1914 are not taken as representing normal costs.

In order to have the cost for each year's operations on a fair basis for comparative purposes, a uniform charge per ton of ore shipped, should be allotted to each for developing and diamond

Yearly Mining Costs—Hidden Creek Mine.

	TOTAL COST PER TON						LABOUR COST PER TON						SUPPLY COST PER TON					
	1913–1914	1914–1915	1915–1916	1916–1917	1917–1918	Half 1918	1913–1914	1914–1915	1915–1916	1916–1917	1917–1918	Half 1918	1913 1914	–1914 1915	–1915 1916	–1916 1917	–1917 1918	Half 1918
Total	1.781	1.025	.996	1.235	1.207	1.372	1.110	.645	.576	.652	.610	.744	.671	.380	.420	.583	.597	.628
Stoping	1.558	.930	.935	1.058	1.059	1.180	.990	.582	.541	.573	.565	.663	.568	.348	.377	.485	.494	.517
Bonus	.....	.....	.072	.148	.164	.307	....	....	.072	.148	.164	.307	....	....	....	....	....	....
Breaking	1.001	.529	.552	.582	.577	.654	.579	.284	.279	.272	.272	.304	.422	.245	.273	.310	.305	.350
Explosives	.271	.188	.197	.200	.203	.203	.033	.018	.013	.016	.015	.019	.238	.170	.184	.184	.188	.184
Drilling	.442	.221	.227	.216	.209	.235	.436	.214	.215	.197	.195	.213	.006	.007	.012	.019	.104	.022
Drill Power	.016	.012	.022	.033	.037	.068	....	....	....	....	....	....	.016	.012	.022	.033	.037	.068
Drill Repairs	.092	.034	.025	.025	.029	.035	.012	.005	.004	.005	.004	.006	.080	.029	.021	.020	.025	.029
Steel	.140	.057	.063	.088	.084	.099	.079	.038	.040	.047	.049	.059	.061	.019	.023	.041	.035	.040
Drill Pipe Line	.040	.016	.018	.020	.015	.014	.019	.008	.007	.007	.009	.007	.021	.008	.011	.013	.006	.007
Handling	.333	.280	.254	.267	.247	.249	.263	.220	.200	.210	.193	.206	.070	.060	.054	.057	.054	.043
Shoveling	.069	.031	.030	.041	.033	.044	.064	.029	.029	.040	.032	.042	.005	.002	.001	.010	.001	.002
Mine Train Loading	.053	.072	.076	.074	.068	.072	.051	.072	.076	.074	.068	.072	.002	.000	.000	.000	.000	.000
Smelter Train Loading	.014	.016	.013	.013	.012	.011	.014	.014	.012	.012	.011	.010	....	.002	.001	.001	.001	.001
Electric Haulage	.081	.050	.045	.048	.042	.043	.072	.043	.039	.042	.039	.037	.009	.007	.006	.006	.005	.006
Track	.027	.012	.007	.005	.013	.012	.017	.008	.005	.004	.009	.008	.010	.004	.002	.001	.004	.004
Car Maintenance	.028	.017	.033	.026	.024	.020	.011	.009	.011	.010	.012	.008	.017	.008	.022	.016	.012	.012
Repairs Tram-Bin	.012	.014	.004	.003	.002	.002	.006	.007	.002	.001	.001	.000	.006	.007	.002	.002	.001	.002
Crushing	.049	.065	.046	.057	.053	.045	.028	.036	.026	.027	.023	.029	.021	.029	.020	.030	.030	.016
Timbering	.044	.033	.025	.050	.051	.052	.027	.021	.016	.026	.023	.028	.017	.012	.009	.024	.028	.024
Expense	.180	.088	.087	.159	.184	.225	.121	.057	.045	.065	.076	.125	.059	.031	.042	.094	.108	.100
Lighting Carbide	.016	.007	.003	.002	.001	.001	....	.000	....	.000	.000	....	.016	.007	.003	.002	.001	.001
Lighting Electric	.011	.006	.005	.006	.006	.008	.002	.001	.000	.002	.002	.001	.009	.003	.005	.004	.004	.007
Overburden	.038	.008	.010	.014	.020	.019	.035	.006	....	....	.002	.009	.003	.002	.010	.014	.018	.010
Office	.018	.008	.009	.016	.018	.025	.010	.006	.006	.011	.014	.021	.008	.002	.003	.005	.004	.004
Surveying	.012	.008	.008	.007	.008	.011	.011	.007	.006	.005	.007	.010	.001	.001	.002	.002	.001	.001
Superintendence	.048	.023	.013	.014	.014	.020	.048	.021	.013	.014	.014	.020	....	.002	....	....	....	.000
Expense	.037	.028	.039	.100	.117	.141	.015	.016	.020	.033	.037	.064	.022	.012	.019	.067	.080	.077
Development	.216	.095	.061	.142	.081	.132	.120	.063	.035	.078	.044	.080	.096	.032	.026	.064	.037	.052
Diamond Drilling	.007	....	.017	.035	.067	.060	....	....	.000	.001	.001	.001	.007	....	.017	.034	.066	.059
Tons per Operating Shift	.....	.....	6.9	7.2	7.9	8.14	....	....	....	....	....	....	....	....	....	....	....	....
Tons per Machine Shift	.....	34.6	36.0	43.8	48.0	49.9	....	....	....	....	....	....	....	....	....	....	....	....
Tonnage	64,930	477,435	725,821	760,705	889,608	403,500	65	477	726	761	890	403	65	477	726	761	890	403
											Thou	. of T	ons					

drilling. The reason is apparent as the amount of development done has no direct bearing on the yearly output. It shows only as a cost item, and is written off against the amount that happens to be shipped during that period.

Assuming a total cost under these headings of 18 cents per ton, the following corrected costs for comparison would be approximately as follows:

1914–15.	1915–16.	1916–17.	1917–18.	1918–19.
$1.10	$1.10	$1.24	$1.25	$1.36

The increased cost of labour and supplies as worked out at Anyox for each year following 1914 is:

1915–16.	1916–17.	1917–18.	1918–19.
15%	30%	50%	65%

Deducting these percentage increases from the corrected costs obtained during the corresponding years, the following results are arrived at:

1914–15.	1915–16.	1916–17.	1917–18.	1918–19.
$1.10	95.8	95.4	83.3	82.4

These are the costs that would have prevailed under 1914 market conditions if the same care were taken in conducting operations. During the second and third periods, the resulting costs, although less than in 1914-15, are approximately equal. This is the time when all of the improvements outlined were being worked out. The next two periods show a decided reduction in operating costs, which reduction almost equals the total increase in the cost of labour and supplies.

The advantage gained from the working of larger stopes and from an increased output, contributed in a minor degree to cost reduction, but the most important factor is the improved methods used in the handling of the broken ore from the first blasting in the stopes and glory holes through the mine to the crusher plant.

THE GRANBY MINES AT PHOENIX

By C. M. Campbell

On June 14th, 1919, the Granby mines at Phoenix, after producing continuously for nineteen years, sent what may be their last trainload of ore to the Grand Forks smelter. During this period of nineteen years the total shipments amounted to 13,678,901 tons. During the busiest years, namely, from 1910 to 1916, daily shipments averaged 3,000 tons; in 1912 and 1913 the average was 4,000 tons per day. Although the available ore resources were approaching exhaustion and a permanent 'close down' was not far distant the immediate cause of the suspension of operations was shortage of coke at the smelter, due to another of the recrudescent strikes (which have been such a curse to industrial operations in southern British Columbia,) in the Crowsnest coalfield.

It is believed that a description of the operations of the Granby Company at Phoenix from start to finish may prove of interest at this time:

Early History

In 1862 placer mining was carried on to a limited extent in Boundary creek. No lode prospecting was undertaken until 1891, following the important discoveries at Rossland in the previous year. Early in 1891 a number of claims in the vicinity of Greenwood were staked, and in July of that year Knob Hill and Old Ironsides claims, in what afterwards became known as Phoenix Camp, were located by Henry White, and his partner 'Matt' Hotter.

Later, an interest in these properties was sold to Jay P. Graves, of Spokane, who was instrumental in inducing S. H. C. Miner, a well known and wealthy manufacturer of Granby, Que., as well as friends of that gentleman, to become large shareholders. In 1901 an amalgamation was effected of the Knob Hill and Ironsides, other properties in the immediate neighbourhood, and the Granby Consolidated Mining and Smelting

Co., of Grand Forks, all of which were controlled by the same interests; and a new company was incorporated, known as the Granby Consolidated Mining, Smelting and Power Co. Ltd. A few years later the control of the company was sold to New York capitalists. At intervals the company has acquired additional properties, so that the mineral claims in the group now aggregate over 1,000 acres, of which less than 200 acres have proved, as a result of exploration, to be mineral bearing.

GEOLOGY

The following description of the geology of this camp is based on O. E. LeRoy's report published in 1911 and also on the results of a large amount of development work conducted since that time. The accompanying plan and sections, Fig. 1, show graphically the occurrence of the ore in relation to the surrounding rocks. In this map, dyke rocks which have an irregular and limited surface exposure and whose course underground is unknown are, for the sake of simplicity, not indicated. For the same reason drift, which in some places is over 30 feet thick, as well as small and thin areas of rock different from that underlying, are not shown on the map. The outcrops of the orebodies are shown by solid cross-hatching, and the area underlain by ore by dotted cross-hatching. With the exception of the Rawhide and War Eagle claims, all the ground on the plan is Granby property.

The rocks are classified as: 'Knob Hill group,' 'Jasperoids,' 'Mineral Zone,' including orebodies, 'Kettle River sediments' and lavas.

Knob Hill.—Underlying the area of Phoenix is the Knob Hill group which comprises the oldest rocks found locally. They are mainly highly altered rocks of igneous origin and are essentially silicious in character containing nearly 91 per cent silica and 2 per cent lime. This formation outcrops extensively. Several holes have also been drilled from different places on the surface to a depth of 1,500 feet. Although none of them has gone through this formation they have all penetrated it, one

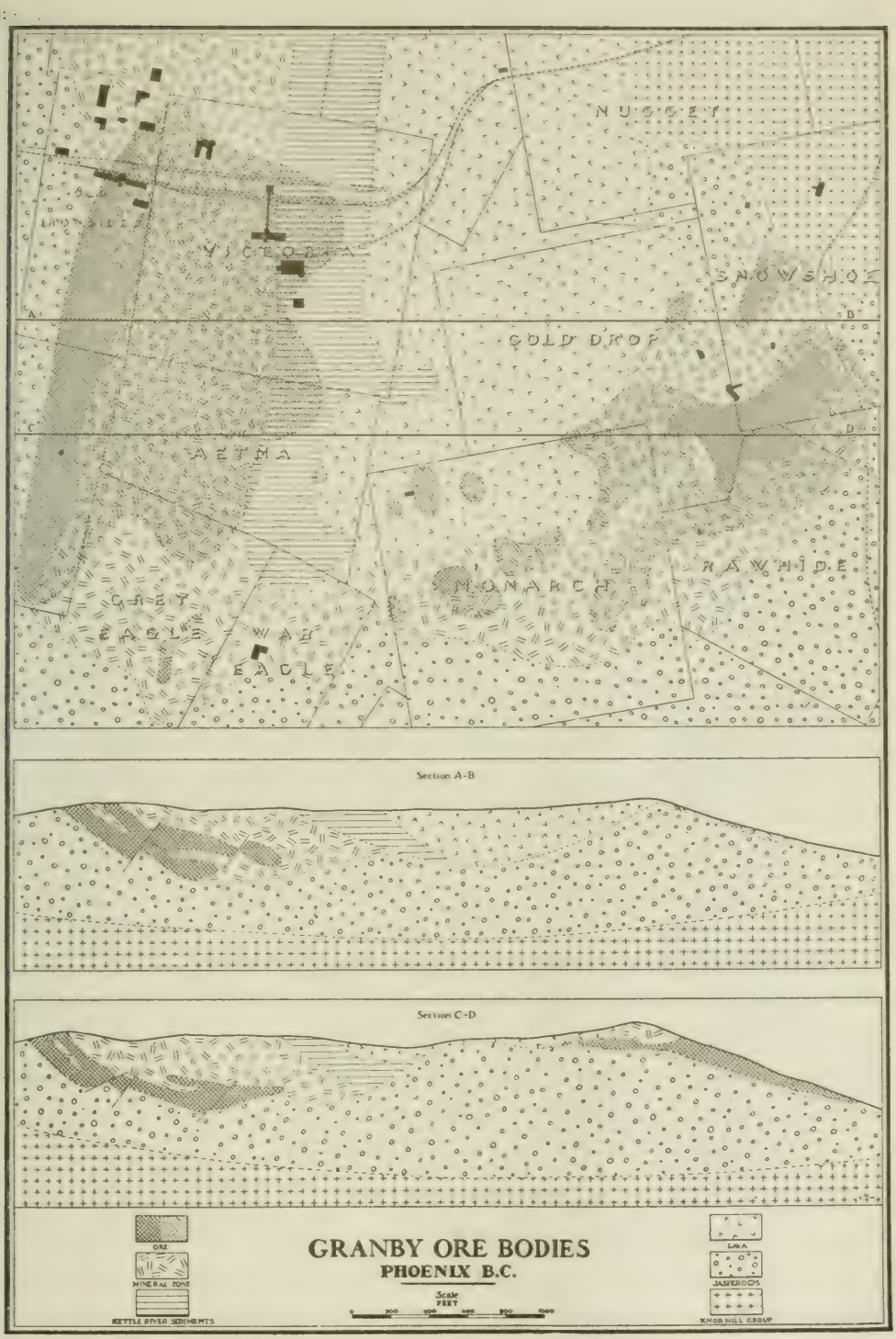


Fig. 1—Plan and sections of orebodies.

reaching a depth of 1,200 feet. No mineral occurrences of value have been encountered. Several rusty showings on the surface have been prospected with negative results. The most encouraging drill hole showed 100 feet of material where the silica content fell to 80 per cent, the iron averaging 5 per cent, the lime 3 per cent, and the sulphur 1.5 per cent; the highest gold assay was a trace; there was no silver and the highest copper assay showed one-tenth of 1 per cent over a distance of 10 feet

Above the Knob Hill group is the zone of jasperoids, and above that is the mineral zone containing the orebodies. These last two types of rock, together with some limestone remnants, form the Brooklyn formation which is considered to have been originally a bed of limestone. None of this limestone outcrops in the map area, although it does extensively at other places in the camp. Underground as marble, containing over 90 per cent carbonate, it is well developed in the northwestern parts of the 200- and 300-ft. levels and was suitable for flux.

Jasperoids.—The jasperoids form a well marked surface exposure. They lie in all cases on the Knob Hill group to which they are firmly cemented by silicious material. In appearance this rock looks like a medium grained breccia or conglomerate. It is usually grey in color but occasionally, due to the presence of iron, is quite red. An analysis shows about 75 per cent silica and 8 per cent lime with varying small amounts of iron. The jasperoids and Knob Hill formations probably have a common origin as regards the source of silica. The siliceous solutions may have been derived from the large grano-diorite batholith which, although exposed in other parts of the district, has not yet been found at depth in Phoenix. In this case it is evident that the silicious solutions were ascending.

Mineral occurrences in the jasperoids are rare and are of no practical value. The instances mentioned below are also of an altogether different type from those in the mineral zone. Some work was done on the Bank of England claim where a segregation of a few tons of pyrite containing some gold was mined. Underground the only drill hole which gave any encouraging indication

was No. 421—this showed 5 feet of ore which assayed: copper, 0.5 per cent; silver, 5.8 oz.; gold, 0.30 oz.; silica, 41 per cent; iron, 16.1 per cent; lime, 7.6 per cent, and sulphur, 17.4 per cent. This ore also contained 1.5 per cent lead—the only occurrence of galena found in the camp. A raise was made to explore further this occurrence and it was found that the drill had penetrated a lens lengthwise, that it was only a few inches thick, and did not contain more than a few hundred pounds of ore.

Mineral Zone.—According to Le Roy, the mineral area is considered to be a zone of contact metamorphism. There is, however, no direct evidence of this. It has been assumed that certain intrusions of the grano-diorite batholith occurring in the district have been the cause of the metamorphism. If such was the cause the mineral bearing solutions given off by the igneous masses sought out the more favourable beds of limestone, then deeply buried under overlying rocks but still in the zone of fracture. The solutions would traverse the limestone in lateral and descending directions, replacing the limestone by lime silicates and later depositing the ore. This view appears to be confirmed by the fact that the ore terminates definitely at depth, giving place to limestone or jasperoid.

The mineral zone is composed essentially of epidote and garnet together with calcite and quartz. The metallic minerals are chalcopyrite, pyrite, specularite, and magnetite, which have been deposited in certain favourable areas, thus forming the orebodies. They are also found in less amounts throughout the mineral zone. An analysis of the rock from the mineral zone beyond one of the orebodies gave about 50 per cent silica, 10 per cent iron, 15 per cent lime, and 1.5 per cent sulphur, whilst these constituents in the ore shipped averaged about 40 per cent, 12 per cent, 18 per cent, and 2.5 per cent respectively. On account of this favourable composition the ore has been self-fluxing.

The orebodies in the mineral zone usually lie along the jasperoid foot-wall and vary in thickness up to over 200 feet. As the sections show, the western outcrop is rather steep, but

with depth this orebody flattens. Many of the orebodies do not outcrop and their existence was determined entirely by the diamond drill. The foot-wall is usually the jasperoid formation and is usually well defined. The hanging-wall is exceedingly irregular. Rich areas often extend well beyond the usual limits of the stopes and in many cases during the periods of high copper prices the ground between orebodies has been profitably mined.

In the orebodies the chalcopyrite, pyrite, and specularite are usually intimately mixed with the gangue minerals. The magnetite usually occurs in segregated masses carrying varying amounts of chalcopyrite and pyrite. Along the foot-wall of the main orebody massive garnet with chalcopyrite is strongly developed. At different parts of the mine a large tonnage of fine ore is obtained in which the gangue mineral is coarsely crystalline calcite. The eastern limb of the main orebody, known as orebody No. 2 (shown in the section), is noticeably more silicious than the rest of the ore. This also occurs banded and this banding may represent structural planes in the original rock prior to replacement.

Kettle River Formation.—Overlying the ore zone is the Kettle River formation of sediments, now largely eroded. This formation, consisting of conglomerates, sandstones and cherty shales, is well exposed in a railway cutting at the mine. These sediments were probably deposited in quiet waters possibly along the margin of a delta. As the material is foreign to the vicinity of Phoenix, it was evidently transported for some distance from an area not yet discovered.

Lava.—The patch of lava shown on the map is part of a flow which originally covered the greater part of the Boundary district, but on account of erosion only isolated areas are now found. Though the local bed has a large surface exposure it will hardly average more than 100 feet in thickness.

Dykes are of limited occurrence on the surface. They have been encountered underground in the orebodies and, with few

exceptions, are found to follow irregular courses. They are seldom over 5 feet thick, and all seem to belong to late periods. The occurrence of dykes has not been a disturbing factor in mining, having been negligible in respect of probably 90 per cent of the ore extracted.

Incidentally, it may be fitting to observe here that the work done in Phoenix by the Geological Survey of Canada proved of the greatest assistance in the development of the Granby Company's mines in this district.

DEVELOPMENT

Active development commenced on the properties in 1896 when work was begun on No. 1 shaft. At that time the country was covered with a dense growth of timber and the nearest railway point was Bossburg, Washington, 60 miles distant. All machinery and supplies had to be hauled by wagons from that point over very rough roads. Nevertheless, the development operations were pushed ahead, the smelter, having two furnaces, was completed, the Columbia & Western, a branch line of the C.P.R. was built into the camp, and the first ore shipment was made in July, 1900.

Shipments in the early days were from Nos. 1 and 2 shafts, both of which were of small capacity, and from No. 1 tunnel, the uppermost of a series of working levels. By 1902, shipments had reached 1,000 tons per day, a daily tonnage which it was expected to augment materially in the near future. At that time very few mines in British Columbia were producing on anything like so large a scale. Most of the mining in those days was done by the square set method. Because many stopes, too big for stulls, had to be filled with square sets, it was considered necessary at first to square set all big stopes in the Phoenix mines. Gradually, however, it was realised that some orebodies did not need this excessive amount of timber. When the stope on No. 1 tunnel sill-floor was being worked, it had a width of 25 feet, a height of 20 feet and a length of over 200 feet. There was not a stick of timber in this stope, and it was considered quite an extraordinary piece of work—and for those days it was.

The fact that Phoenix ore would stand unsupported, as in the case of other mines such as the Treadwell where conditions were similar, led to a vital change in the method of local mining.

The cars used at that time ran on tracks (12-lb. rails, and 18-in. gauge) between the posts, and were of the square steel box, 1-ton capacity type, fitted with the then famous Anaconda axle. All cars were pushed by hand to the shaft-house, where they were caged, hoisted, taken to the bins, dumped and returned to the cage. Such was the procedure around a mine early in the century. Such companies as maintained these methods were able to do so because in many cases their tonnage was small and the grade of their ore sufficiently high. The copper recovery at Phoenix in 1902 was 27 pounds per ton of ore; this was less than that of the previous year and with leaner years in sight, a reduction in costs was imperative. A further appreciable reduction in costs without a change of methods was impossible; hence exceptional methods in use at large mines elsewhere were applied, or introduced, and original schemes were also devised. In 1902, one man out of every ten was a timberman, and the timber cost amounted to 34 cents per ton. By entirely changing the system of mining, in less than two years this cost was reduced to 4 cents, and later to 2½ cents. Material reductions were also made in handling costs. Altogether the total cost which in 1902 was $1.71 per ton, was rapidly reduced until in 1906 it was 97 cents. After that the reduction was gradual until 1913 when it reached its minimum of 75.4 cents, and, during this year, the ore from the tunnels, amounting to over half a million tons, was shipped at a cost of only 65.5 cents. All costs mentioned refer to ore crushed to 6-in., on cars, including all development and general expenses. Further expansion during the early years consisted in the development of Nos. 2 and 3 tunnel levels and the equipment of each of these with bins and crushers, as well as railway 'terminal' facilities. The Great Northern built into Phoenix in 1904 and gave another desired outlet for the ore. The acquisition of the Gold Drop and adjacent properties was made in 1905, and these were developed and equipped during the following year. The con-

Plate I—Square sets of a former period being demolished.

struction of the Victoria shaft and headworks was completed and in operation by July, 1907. About this time the smelter was also enlarged to eight furnaces. This completed the development. The property then comprised the Knob Hill-Ironsides mine developed at intervals of 100 feet, by the Nos. 1, 2 and 3 tunnels and the 200, 300 and 400-ft. levels, and the Gold Drop mine with a series of levels of its own. These were divided into four different units. The No. 2 terminals handled the ore above that level including the ore around No. 1 tunnel, which by that time had become nothing more than a manway. Ore from here was shipped by the Canadian Pacific, although connection was made with No. 3 tunnel so that crushed ore could be hauled to the bins on the Great Northern. No. 3 tunnel terminals handled the ore between this level and the one above, and this ore was all shipped by the Great Northern. The Victoria shaft equipment handled all ore from the lower levels referred to and shipped on either railway. The fourth unit was the Gold Drop which shipped by the Canadian Pacific. Each of these units had a distinct and complete equipment of rolling stock, crushers and bins, and were manned by separate crews under separate shift-bosses.

So many different units instead of one central outlet would ordinarily add to the cost per ton. It must be remembered, however, that the ore was not concentrated in one central deposit but spread over a large area in separate bodies so that the method used was the only economical way of handling the ore, and in addition there was the advantage of the almost absolute certainty of being able to make up the day's shipment should anything go wrong with one of the units.

UNDERGROUND MINING METHODS

Underground methods in Phoenix have been largely the result of evolution and to some extent are peculiar to this district. Originally, as stated, square sets were the rule, but this method was found not only prohibitive from a cost standpoint but also unsatisfactory from a safety standpoint, and was discarded 17 years ago. Square sets, no matter how heavily reinforced with

timber and cribbing, did not prevent masses of rock from crushing through; with open stopes the ground could be examined to better advantage.

In working out the upper part of the main deposit where the foot-wall dipped at about 45° or over, and where there was a uniform width and an extended strike, the method was to drive parallel drifts along the strike with raises at intervals of 50 feet. These raises were connected at two places between levels and pillars thus set off. Stoping was continued by means of raises from the parallel drifts so that the solid orebody was changed into a series of pillars. This stage is well shown by Plate II. The nature of the ground would by this time be exposed, many pillars could usually be taken out without endangering the whole stope. The remaining pillars which usually had been drilled as stoping progressed could then be blasted simultaneously and the roof allowed to cave. Finally the ore was drawn from the chutes until the waste appeared.

More recent work has been in irregular areas, often of comparatively small size and either independent of, or off-shoots from, a larger body. In a general way the scheme used is that shown in the 'movie' sketch.

In this instance, it is supposed that an orebody has been located by drill holes as shown in stage 1. The nearest level is then extended to explore it further and a raise is put through to the surface or to an upper level mainly for ventilation purposes, although it is often used as a manway. Stoping is then begun with one or two machines and development continued. Stage 4 shows two small stopes started near the bottom of the orebody. Working in this way the roof is always within reach of the ladders, and usually within reach of a bar, and can be examined and 'scaled' if necessary. In stage 5, the bulk of the ore is seen to have been extracted. The ore lying at the bottom will probably have to be shoveled while that remaining can be broken down piece by piece. In this instance the remnant could all be drilled from 'set-ups' in the drifts and all the remaining ore broken down with a big blast. This is often the

Plate II—Stope showing pillar arrangement.

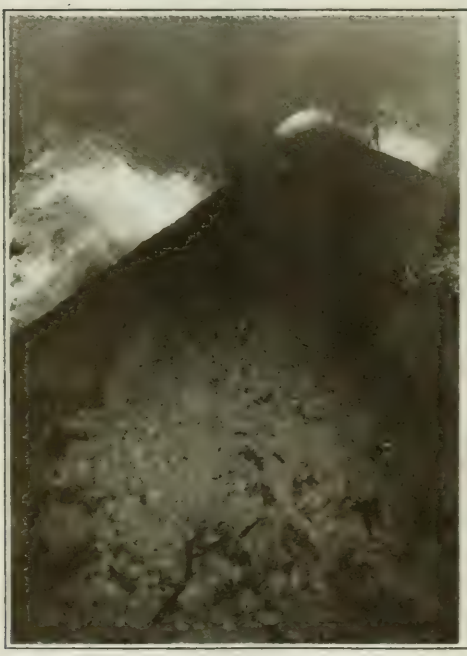


Plate III—Stope nearly filled with waste.

Plate IV—Stope partially filled with waste.

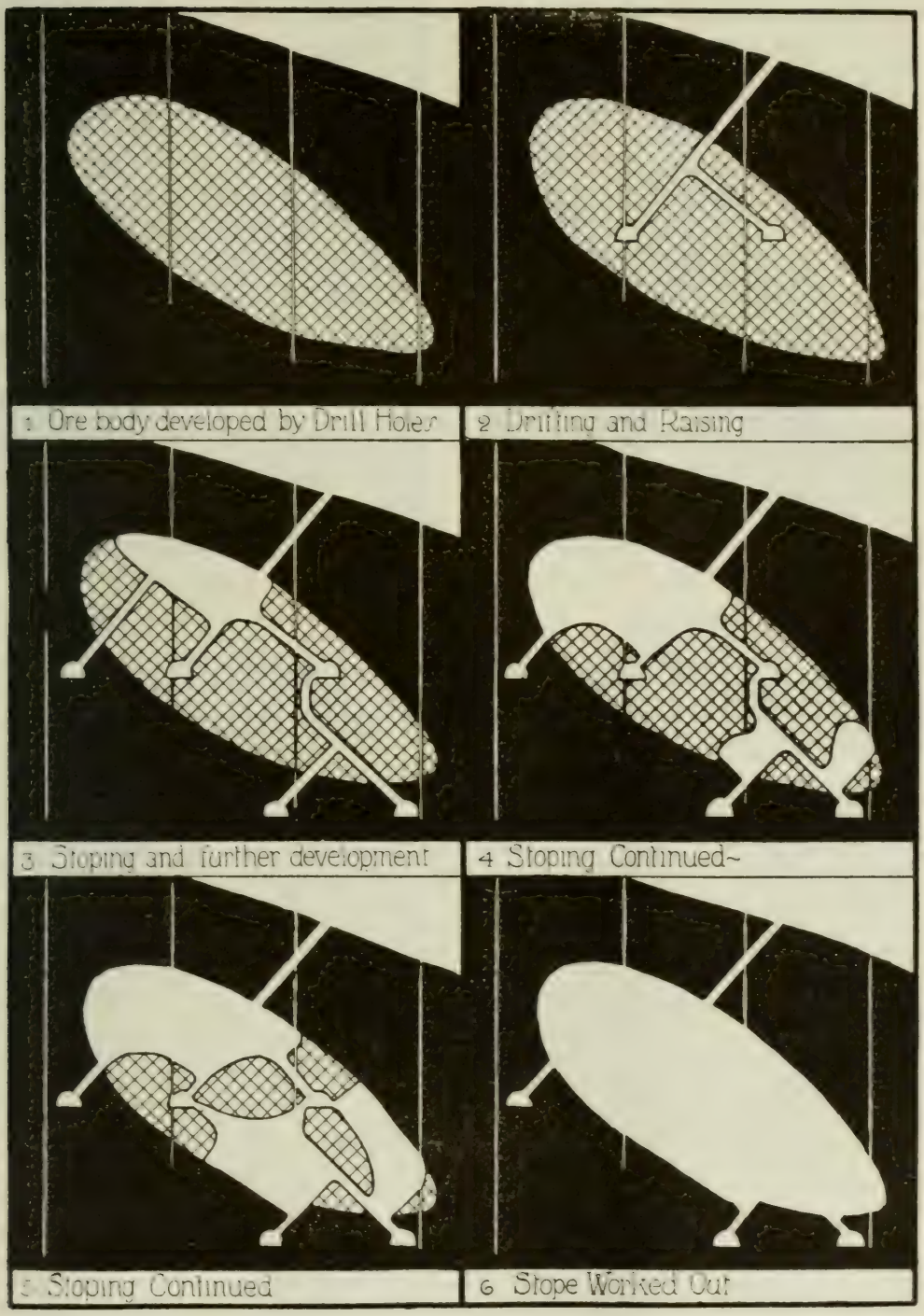

1 Ore body developed by Drill Holes
2 Drifting and Raising
3 Stoping and further development
4 Stoping Continued~
5 Stoping Continued
6 Stope Worked Out

Fig. 2—'Movie' of a Granby mine stope.

method used, although in this case some waste is apt to break off from the roof and mix with the ore. The roof freed from its support is also apt to cave through to the surface. Should it cave, the ore is drawn from the chutes until the waste appears and then operations cease. Should the orebody extend for a considerable distance on each side of the section shown, the procedure has been to leave supporting pillars at suitable intervals. These are drilled as extraction proceeds and when the rest of the ore has been extracted the pillars are blasted and the broken ore drawn from the chutes.

On the Phoenix side of the hill, because of railway tracks and surface plant, there are sections where the ground cannot be caved. In these cases the pillars have to be left in the mine and the ground is further protected by waste and rock dumped into the stopes through raises, similar to the ventilation raise referred to above. Stopes have in many instances been tightly filled by this means.

It would, of course, have been better policy if the surface buildings and tracks had been placed in areas not underlain with ore. This would have been possible. The financial condition of the Company in the early days did not, however, permit of a comprehensive exploration scheme. The result has been that some ore which otherwise could have been recovered has, of necessity, been left as a support.

Plate III illustrates an example of a nearly filled stope. The stope in question, situated almost under the Victoria shaft-house, originally contained a large supporting pillar, from the top of which a raise extended diagonally to a drift on the 200-ft. level. This pillar was removed, leaving the mouth of the raise at the apex of the stope. The stope was then filled with waste as shown. Later, a few rounds from the collar of this raise allowed a further large tonnage to be run into the stope so that it is now practically filled. From other stopes nearby raises were driven which reached the surface at different sides of the shaft waste-pocket, and for years all the shaft-waste was returned directly back to the stopes with no rehandling whatever.

Plate V.—Gold Drop main stope —north side.

Plate VI—Gold Drop main stope —south side.

Plate VII—Gold Drop main stope, after pillars between north and south sides were removed.

Occasionally, the raises would become blocked with fines. A stream of water would then be allowed to flow down the raise for some time, and the whole mass, eventually becoming saturated, would be flushed out of the raise and carried down against the far walls of the stope, where it would pack very tightly. Plate IV represents a stope above the 200-ft. level which was worked through to the surface. It has since been completely filled.

Where it was not necessary to fill the stopes some very large openings have been made. This was particularly the case at the Gold Drop mine. Plates V, VI, and VII illustrate the main Gold Drop stopes. The pillars shown on the right in Plate V are the same as those shown in the centre and at the left in Plate VI. These pillars were afterwards blasted and the stope then presented the appearance shown in Plate VII. This stope, as it then appeared (and it remained in this condition for about a year before it caved), was the largest stope at any time opened up in the Granby mines, and it will bear comparison, in point of size, with any in the world. The area free from pillars had an average length of 400 feet and an average width of 150 feet. The height was 80 feet, though in some places where the foot-wall had been cut away in order to let the ore run, the height was nearly 100 feet. This area was absolutely unsupported and the tonnage extracted from this stope is estimated to have been 400,000 tons. In addition to this there were several off-shoots from the main body, which, when mined, resulted in connecting stopes so that the one big stope, including branches, yielded over half a million tons.

It is seldom that underground mining work presents anything to which the adjective 'beautiful' may be applied, but the northern side of this stope especially, of which a reproduction has been attempted in Plate V, dimly lighted from the front and with its gracefully arched roof, presented an appearance that was eminently picturesque.

Plate VIII shows a stope on the Monarch claim of the Gold Drop mine. The discovery of an orebody here was made

Plate VIII—Stope which has caved after blasting the pillars.—Note slip at upper left-hand corner.

as a result of the driving of Monarch No. 1 tunnel. It was cut unexpectedly while driving towards another orebody. As shown in the plate, the top of this orebody came within a few feet only of the surface. Over 100,000 tons were developed and practically all this tonnage was shipped, the stoping loss being almost nil. The extraction of the remaining pillars recently caused the roof to fall in, caving being facilitated by the slip shown at the left. Almost all this ore was drawn from one chute —probably a record for a chute.

Another stope is also worthy of record though it lacks the spectacular features of the main Gold Drop stope. The deposit worked in this case was in the Knob Hill-Ironsides mine at the south end of No. 2 tunnel just above that level. It was almost flat, roughly circular with a diameter of 260 feet, a thickness of from 20 to 70 feet, and contained nearly 200,000 tons of ore. Between the orebody and the surface was 200 feet of rock. The ore, with the exception of that contained in seven supporting pillars, was extracted. The power line on the surface, directly over the stope, was then relocated and the pillars blasted to recover the ore, but the ground did not cave and has not yet done so although it has been undermined now for over four years.

Other orebodies forming the Knob Hill-Ironsides group were also completely extracted, but generally speaking the great size of the main orebodies, the fact that in certain areas the roof was bad, and that strong permanent supports had to be left in stopes underlying surface works, made it imperative that considerable ore, which can never be recovered, should be left in place, so that the remarkable low stoping loss obtained at the Gold Drop can not be expected at the larger mine. At the time of the 'shut down' 83 per cent of the estimated ore had been recovered.

Development work at all the properties amounted to 2,522 feet of sinking, 76,565 feet of raising, 89,794 feet of drifting and 126,153 feet of diamond drilling. This means .16 ft. of sinking, .48 ft. of raising, .56 ft. of drifting and .79 ft. of diamond drilling

for every 100 tons of ore developed, or 17 cents per ton on the ore shipped.

SURFACE MINING METHODS

On account of the large tonnage of ore occurring at the surface, power-shovels were in use as far back as 1903, three being in operation at one time. Later, however, it was found that only one could work to advantage and this machine, working on No. 1 tunnel level, did good work until about 1906, when the crusher which it supplied was destroyed by fire. In consequence of the limited reserves on this level the new crusher was built at the No. 2 level below and was supplied with ore obtained by underground methods. In course of time all ore was extracted with the exception of that in pillars and around

Plate IX—Telephotograph of Granby surface workings about 1908. The outcrop of No. 2 orebody is indicated by the small pits.

drifts. There was also the zone of waste between the two main orebodies. Plate IX will give an idea of this stage. Mining operations were carried somewhat further than shown in the

photograph, and the surface was allowed to cave section by section. Instead of handling this ore from a lower level it was considered good policy to return to the power-shovel method for the following reasons:

1. Waste could be handled more cheaply by loading larger masses direct instead of by drilling and blasting and then handling from the lower level.

2. Ore could be handled quite as cheaply, with the additional advantage that no development work was required.

3. Ore could be cleaned up to the sill floor, thus giving longer life to the crusher at that level and eliminating the hoisting charge on some of the ore, mined above No. 3 tunnel, that would otherwise go to the shaft.

4. Where ore and waste were more or less mixed, a better separation could be obtained.

5. All mine cars could be loaded to their fullest capacity.

Plate X—The glory hole in 1917.

Plate XI—A barman at work in the glory hole.

Plate XII—Steam shovel handling large masses of waste.

A 40-R Bucyrus electric-shovel was therefore purchased and put in operation on No. 2 tunnel sill-floor. It had nearly completed its work on this level after five years of successful service when the mine was closed. A photograph of the pit as it appeared in 1917 is shown in Plates X and XI. At that time the face was 200 feet high. Plate XII shows details in connection with electric shovel work. Costs per ton for material handled ranged from 40 cents per ton during the first year of the war to 57 cents in 1918. As the ore only represented part of the output, the cost per ton for ore alone was naturally much higher. The waste, however, was not altogether a loss since much of it was used advantageously in stope filling.

HANDLING THE ORE

Reference has been made to the necessity of reducing costs by improving methods, and with this in view the several operations in handling the ore were carefully checked. Chutes with an opening three feet square were constructed instead of the small ones previously in use. These chutes were equipped with a steel arc-gate, although finger-gates were occasionally built in. 'Bulldozing' chutes such as are used in some big mines were never considered necessary, but an approximation to that type was often made by driving a manway to tap the raise above at one or more places.

Cars of the Granby type were used on all levels. These cars, which were designed and put in operation by the officials in charge about 1904, were then a novelty in ore handling. Since that time they have been adopted by several of the larger mining companies in different parts of the continent. Previous to the introduction of these cars, hopper-bottomed cars of 10-ton capacity seemed to be the best on the market. While very satisfactory when the ore was small, it was found that, as the bulk of the ore was coarse, the contents often had to be blasted out of the car. This caused loss of time, extra cost for powder and labour, and a heavy car repair expense. These cars also lost some ore along the track which kept a man busy cleaning up. The 'side-dumper' has none of these defects. The dump

Plate XIII—View of Granby dump-car underground.

block used is cheaply constructed and can be easily removed from place to place when waste has to be distributed in abandoned stopes. Equipped with M.C.B. couplers and roller bearings they have added greatly to the efficiency of the plant.

Mine locomotives in use are of the electric type, 3-ft. gauge, except in a few places where a narrower gauge track is used. Our experience, however, has been that, when heavy tonnage is to be handled, a 3-ft. gauge track justified the extra expense.

The Victoria shaft was equipped to handle 2,500 tons in 24 hours, which capacity was maintained during the years of heavy output. The shaft is on an incline of 60° and contains two skipways and a manway. Each skip has a capacity of 5 tons. Large ore pockets have been cut below the 200-ft. and 400-ft. levels. The 200-ft. level has no waste pocket as all waste from this level has been used for stope filling. The 400-ft., being the lowest level, has a waste pocket, and waste from here is hoisted and run back into the mine from the surface. The skips dis-

charge into bins and thence the ore goes to a jaw crusher with a 30-in. x 42-in. opening. A travelling belt carries the crushed ore to bins between the C.P.R. and G.N.R. tracks. With the pocket and bin storage indicated and in addition the presence of a good supply of empty ore cars on one road or the other there has never been a delay on account of lack of storage. An important detail in connection with this equipment, which has now been in use for 15 years and which has given a great deal of satisfaction, is the type of finger-gate used on the chutes. The Victoria installation is typical of those at Nos. 1 and 2 terminals and at the Gold Drop, the chief difference being that the Victoria has a hoisting plant in addition. For this reason the other outlets will not be referred to further.

This concludes a description of the first phase of Granby work at Phoenix—essentially a period of large scale operations. Whether conditions will again be such that operations will be resumed is for the future to decide.

MINING METHODS AT THE MOND NICKEL COMPANY'S MINES

By O. Hall

The Mond Nickel Company at present operates five mines Bruce, a somewhat historic old copper-quartz mine; Victoria, their oldest nickel mine, now at a depth of 3,000 feet; Garson, Levack and Worthington.

At Bruce narrow copper quartz veins are being mined by shrinkage over stulls.

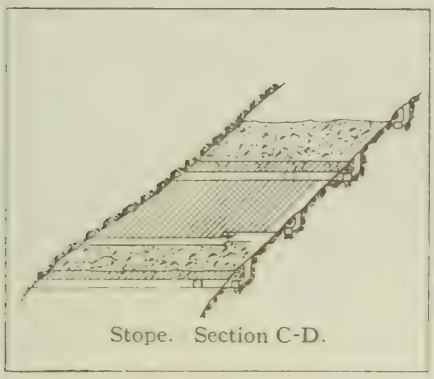
At Victoria a relatively small but persistent ore-shoot has been mined out largely by underhand stopes.

General view of surface plant at the Garson mine

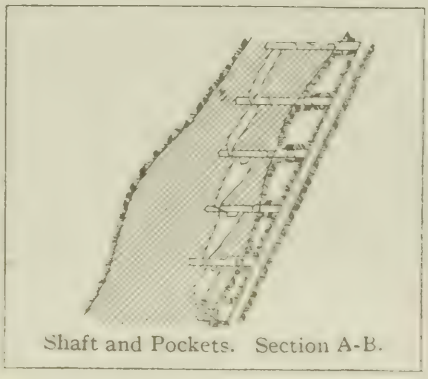
Garson, the largest producer during the past ten years, calls for a variety of mining methods. A system of orebodies rather than a single orebody is mined. Two or three years' work in diamond drilling, drifting and section-cutting is necessary on each successive level, and conditions are such that the mining method can only be decided upon after the more important

problem of finding the ore has been solved. About one-half the body has been mined by underhanding into mill holes; but with the adoption of the water drill, shrinkage stoping is being largely used and the larger stopes are mined as at Levack. Much of the description given hereunder in respect of methods at the Levack is applicable also to the practice at the Garson.

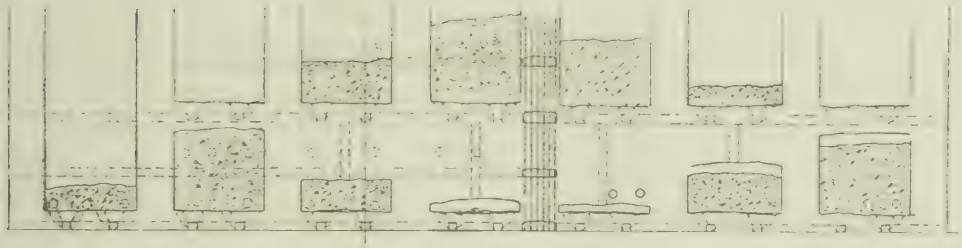
At Levack and Worthington relatively symmetrical bodies are being mined, and a definite mining system is followed.



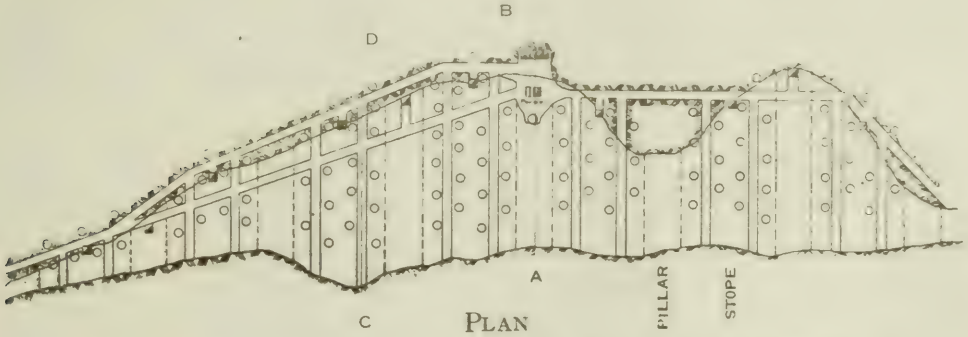
Stope. Section C-D.



Shaft and Pockets. Section A-B.



VERTICAL PROJECTION



PLAN

METHOD OF MINING.—LEVACK MINE—MOND NICKEL COMPANY

Levack Mine

Conditions.—The orebody has a maximum length of 1,200 feet, and a thickness of 20 to 200 feet. The foot-wall is very irregular, its dip varying from 30° to 70°. Hanging- and foot-wall are greenstone or gneiss, chiefly gneiss. The ore is tough, and the walls stand well. As the orebody dips under a muskeg, and a creek draining a large water basin runs through the muskeg, caving might result in flooding. Ample pillars must be left.

Method of Mining.—The method of mining resembles that used at the Alaska Treadwell. The mine is divided into 40-ft. pillars and 100-ft. rooms. The pillars and rooms are approximately at right angles to the strike. The pillars are rib pillars continuous on the dip. The rooms are completely mined out, no floors, being left. Shrinkage stopes are started above each main level and carried through the roof and floor of the level above. The pillars above a pinch at 800 feet are being left until the balance of the orebody is out. Their final extraction may necessitate partial filling.

Development.—A central five-compartment shaft has been sunk at 65° in the foot-wall. Main levels have been cut at vertical intervals of 120 feet. Intermediate stations have been cut and sub-levels 60 feet above main levels are driven where the orebody is flat. Main levels are developed by drifting to the ends of the orebody and crosscutting to foot- and hanging-wall. Two crosscuts 50 feet apart are driven under each stope. Where the dip is under 60°, the crosscuts are run about 20 feet into the foot-wall and a drift run along the foot-wall. Short mucking raises are run up from the sides of the crosscuts and from the foot-wall drift. These are spaced at 35-ft. centres and are shaped to use chutes of the Creighton type or steel plated platforms sloping 10° the latter being used only where excessive block-holing or sand-blasting is expected. When the mucking raises are ready, the stopes are section-cut 20 feet above the level and the draw holes funneled out. Ventilation and manways are provided by running raises up the centre of each stope on the foot-wall, also in each alternate pillar. When the dip is

General view of surface plant at the Levack mine.

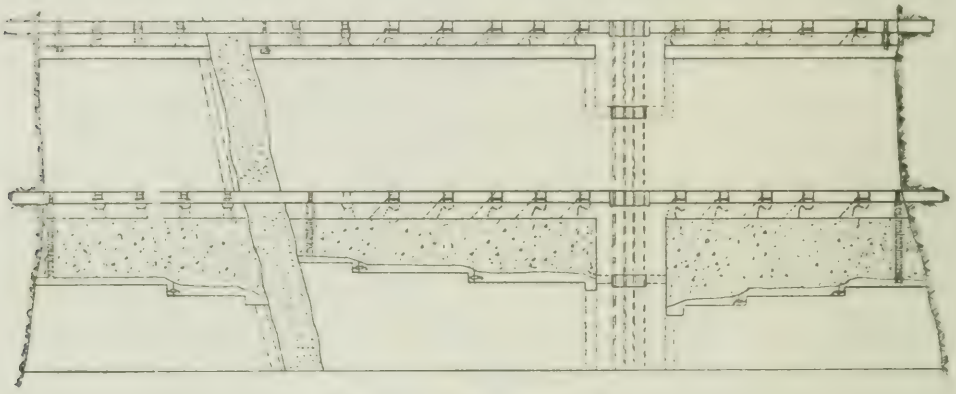
under 50°, short drifts are run from the raises to determine the foot-wall 60 feet above the main level. A foot-wall drift is then run from the sub-level station. The stopes can thus be entered from the sub-level or level above or through short drifts driven into the pillar raise. Steel and tools can be lowered into the stope through the stope raise and lowered out via the pillar raise. Ventilation is up the pillar raise and out the stope raise. A system of ore-pockets has been cut in the shaft-pillar as shown in section A-B. Foot-wall drifts facilitate mucking, permitting 'empties' to travel in one way and 'fills' out another. Where this is not important, draw-holes are placed at the foot-wall end of the crosscuts and the foot-wall drift omitted.

Stoping.—The stopes in the wider portion of the orebody have fairly large dimensions, 100 feet from pillar to pillar and up to 200 feet from foot- to hanging-wall. All the larger stopes are mined by carrying breasts from foot- to hanging-wall. Starting at the foot-wall raise, a slice is cut out of the roof from pillar to pillar. The machines then face the hanging-wall and carry a

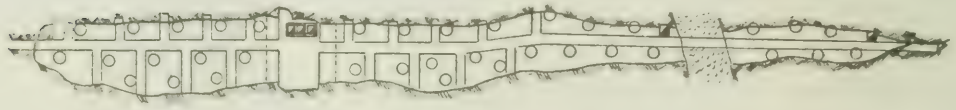
10-ft. breast to the hanging-wall, drilling three horizontal rows of holes. The horizontal spacing between holes is about 7 feet, the vertical 3 feet. The breast is usually blasted in three blasts, large chunks being block-holed after each blast, the lower row of holes being blasted first, followed by the second and third. The roof often rips ahead of the holes, producing irregular breasts, but an attempt to drill symmetrically always pays. Stoping is carried past the sub-level and through the floor and roof of the level above. The stopes most distant from the shaft are mined first, to ensure the level above being finished before the ore from below breaks through.

WORTHINGTON MINE

Conditions.—The orebody has a length of about 700 feet and a thickness of 20 to 60 feet. The dip is about 70° at the surface, but steepens and is nearly vertical at 1,000 feet.



VERTICAL PROJECTION



PLAN OF LEVEL

METHOD OF MINING.—WORTHINGTON MINE—MOND NICKEL COMPANY

Mining Method.—Shrinkage stoping is used. A shaft-pillar divides the body, the orebody east and west of this being mined as separate stopes. A dyke in the upper levels divides the easterly end.

Development.—A shaft has been sunk in the foot-wall and a 60-ft. pillar left opposite. Levels down to 750 feet have been cut at approximately 150-ft. intervals; after this at 250 feet. Stations have been cut in the shaft-pillar and a main drift runs east and west to the ends of the orebody. Crosscuts to foot- and hanging-wall have been run at 40-ft. intervals. Short mucking raises or draw-holes are driven up from the crosscuts and chutes are built to act as muckways. Platforms, 3 feet higher than the cars, and chutes built in the centre of the platform, covered by three 80-lb. rails spaced 18 inches, have been found very satisfactory for mucking, combining the advantages of a block-holing chamber and a chute. Where the orebody is not over 50 feet wide, a main drift 15 feet from the foot-wall and draw-holes on either side, 35-ft. centres, are found more convenient than crosscuts, but crosscuts are somewhat necessary to locate the walls and place the draw-holes. Section-cutting 20 feet above the level follows the cutting of the draw-holes. It starts at the shaft-pillar and is carried to the ends of the orebody.

General view of surface plant at the Worthington mine.

Stoping.—The shaft-pillar and a dyke in the easterly end divide the orebody into three stopes. Raises are run up the shaft-pillar and along the dyke. Cribbed manways are carried up the opposite ends of each stope. Ventilation is up the cribbed manway and out the raise. Stoping starts at the raise, and a slice is cut from foot- to hanging-wall, the first round of holes being drilled from a cross-bar in the raise. The machines then face away from the shaft-pillar and carry a breast to the end of the orebody. Up to 1916 piston drills were used, the earlier types of water drill being too light for our conditions. With piston drills the roofs were carried on a down slope to permit wet holes. With water drills, the roofs are kept level. A breast of about 9 feet is carried, three horizontal rows of holes being drilled; the holes are spaced about 3 feet vertically and 6 feet horizontally. Holes are drilled parallel to the walls. Where conditions permit, machine men are paid by the cubic yard. Where rapid extraction is required, two or three benches are carried. The three rows of holes are blasted in succession, large chunks being block-holed after each blast. When there is no blasting or scaling, water drills complete about 50 feet of drilling in an 8-hour shift, but as scaling and blasting usually occupy 40% of the time, the average drilling per shift is reduced thereby to about 30 feet. The amount broken is about one ton per foot of drilling. The Worthington orebody is fairly regular and stoping has been systematic.

GENERAL

The description given applies to the main bodies at Worthington and Levack. Worthington has small extensions which have not been mined. Levack has a flat expansion with a known depth of about 300 feet and a maximum area of about five acres. This expansion of the orebody is over one half rock and will require economical mining. A method for this has yet to be devised.

THE INTERNAL CORROSION OF WIRE CABLES AND A SUGGESTED METHOD FOR ITS DETECTION.

By Wm. Fleet Robertson.

(Annual Meeting, Montreal, March, 1919)

This paper owes its origin to a fatal accident which occurred in the Protection Island shaft of the Canadian Western Fuel Company's colliery at Nanaimo, B.C., on September 10th, 1918. By this accident 16 men were instantly killed through the hoisting rope breaking, thus dropping the cage to the bottom of the shaft. A coroner's inquest was held in Nanaimo, and a Governmental investigation ordered as to the cause of the failure of the rope, the writer being called upon to make this investigation.

To give an intelligible account of the occurrence it will be necessary to describe in brief outline the colliery at which the accident occurred.

The Nanaimo Colliery was opened up about 1853 by an English company—the Vancouver Coal Company. A pair of circular shafts were sunk within a few feet of the shore of Nanaimo harbour and cut the Douglas seam of coal at a depth of about 603 feet. This shaft to-day is known as the No. 1 Esplanade shaft.

The coal was found to be dipping to the east, i. e. under the harbour at a low angle, about ten degrees.

At the entrance to the harbour there is an island (Protection Island), under which the coal-beds extend, and later a shaft was sunk there, known as the 'Protection Island Shaft,' which cut the Esplanade shaft seam at a depth of about 630 feet.

This shaft was fully equipped and for years hoisted coal. Eventually the underground workings of the Esplanade shaft and the Protection island shaft connected, the direct distance between the two shafts being about 1½ miles.

For economic reasons it came about that the hoisting of coal was discontinued at the Protection Island shaft, the entire output being raised through the Esplanade shaft.

Protection Island shaft ceased to be used as a coal hoisting shaft about 1904, but was continued in use for the lowering and raising of men working in that part of the now extensive workings.

A small amount of coal continued to be raised here, but only enough for steam for a fan, air compressor, pump and the hoisting engine, the records showing that this amounted to less than 1,000 tons a month in two cages, or about 500 tons per rope.

At the Esplanade shaft there was hoisted from 15,000 to 20,000 tons of coal a month on each rope together with a greater number of men than at the Protection Island shaft and all the mine timber, etc.

The hoisting plant at Protection Island shaft was steam driven, thehoisting drum being cylindrical, 10 feet in diameter, and the head-sheave being 10 feet in diameter. The hoisting cable was 1½ inches in diameter—Langs lay, of crucible steel wires, six strands of sixteen wires each around a hemp centre about ¾ inch diameter.

The shaft was vertical, and each compartment was fitted with four wooden guides 4¾ x 4¾ inches. The cage was provided with four pairs of safety clutches, a pair on each guide, brought into operation by four pairs of tension spiral springs, 3 inches in diameter, of 1½ inch round steel. Each spring when new, as shown by subsequent tests, had a safe elongation within the elastic limit of 30% when it had a pull of 1,200 pounds.

Why these safety clutches failed to work is an unanswered question, but they never touched the guides. Possibly it was on account of its being a descending trip, and, as the rope broke 179 feet above the cage, the lash of the rope may have kept the clutches out of action.

The shaft was used as an intake-air shaft, being housed over the top and in circuit with a forcing fan, the air being used as an auxiliary to the general supply.

The shaft was very wet; the water falling in it was free from acid, but was somewhat alkaline, carrying:

Calcium sulphate	14	grains	to the	gallon
Calcium chloride	103	"	"	"
Magnesium chlorite	190	"	"	"
Alkali chlorides (soda and potash)	1,262	"	"	"

The rope which broke had been installed on March 6th, 1915, and broke on September 10th, 1918, a service period of 1,282 days, or almost exactly 3½ years.

The rope broke 179 feet above its point of attachment to the cage, and as nearly as can be ascertained the break occurred about the time the point of weakness had just passed over the head-sheave on a descending trip.

The load on the rope as nearly as can be obtained was:

Weight of car	4,357 lb.
Weight of 179 feet of rope	540 lb.
Weight of men	2,720 lb.
	7,617 lb., say 4 tons.

The evidence was that the cables were examined almost daily by a man appointed for the purpose, but his examination consisted of allowing the cable to pass slowly through his gloved hand, or holding a piece of stick against the moving cable, a practice that might detect broken or projecting wire ends, but gave no indication as to internal corrosion of the cable.

The method of lubrication consisted of frequently applying cold ordinary black lubricating oil on waste or burlap to the cold cable but the oil evidently did not penetrate the cable at all.

Three coils of the cable, of about 100 feet each, were taken to Montreal and tested in the physical testing laboratory of McGill University for tensile strength under the supervision of Professor H. M. Mackay, with Mr. S. D. McNab in charge of the laboratory.

One coil of the cable was from the hoisting drum and had always been under shelter and not exposed to the shaft conditions. This part of the cable, test No. 1, stood up to a strain of 80 tons which was 89.35% of the aggregate strength of the individual wires tested separately and was above the guarantee of the makers, T. & W. Smith, Ltd., Newcastle-on-Tyne, England, of 78 tons for the new rope, and represented a tensile strength of the steel wires equivalent to 208,000 lb. to the square inch.

The test indicated a cable well made and of first class material.

The accompanying sketch shows the positions from which test pieces were taken and their respective breaking strengths.

These tests showed conclusively that deterioration of the rope was 'spotty', following no order of progression and apparently was unaccounted for by any local conditions in the shaft. They also illustrated the futility of putting any reliance upon a test for tensile strength made on a piece of cable cut from the portion next to the cage.

A close examination of the external surface of the cable failed to show any wires with ends broken, worn or projecting, the usual danger signals when the cable is failing from wear. The wear or the rusting of the externally visible wires was not such as to cause apprehension.

Photomicrographs by Dr. Stansfield showed conclusively that no crystallization had taken place in the steel of the cable.

An examination of the fractured ends of the test pieces settled so conclusively that the failure of the cable was entirely due to the corrosion of the internal wires that further search was unnecessary. The wires externally exposed had been subjected to frequent applications of an oily rag which supplied a sufficient superficial lubrication to protect the wires externally to a great extent, but the interior of the cable had evidently been absolutely devoid of oil, or other protective agent, and the wires internally were very badly rusted, many of them corroded

to threads and others completely eaten through; in fact, in test No. 5, in opening up the ends for attachment to the grip, thirty-two wires were picked out completely severed.

It became evident that the strength remaining in the cable was approximately in proportion to the cross-sectional area of the wires remaining unoxidized, the quality of the steel remaining about the same as in the unrusted wires. This was so evident that a visual examination of the broomed-out end of a test piece enabled a very close estimate to be made in advance as to what the breaking strength of the test would be.

Conversely the breaking strength of the portions of the cable is a fair index of the amount of oxidation that had taken place in these respective portions.

The results of these tests have emphasized most strongly the fact that the external condition of a cable is no criterion as to its remaining strength in cases similar to the one described.

Of course, if a cable is subjected to very heavy external wear it will deteriorate from that cause, possibly before internal corrosion could have become important, but such deterioration, being visible, ceases to be dangerous.

In the case under review, however, the external appearance of the cable would lead any rope inspector, such as is usually employed, to believe the cable to be perfectly safe, whereas it was a 'whited sepulchre' and rotten inside. That this is not a special case, but has a much wider application, was brought to my notice by a piece of $1\frac{1}{4}$ inch cable from a Sudbury mine which came in to the McGill laboratory to be tested during my stay there. This cable from all outward appearances seemed practically as good as new, but the tensile test and the broken ends showed the cable to be internally rotten with rust. A subsequent critical examination of the interior of other cables made by the British Columbian Mines Inspection Staff further indicates the disease to be only too prevalent. In my opinion the remedy is internal lubrication with suitable oils, beginning when the cable is new and repeated at short intervals; for, if the rust is allowed to get started it is difficult, if not impossible, to stop it. As to how this internal lubrication

can best be effected is a question, but I am convinced that to be effective, the cable must be immersed in oil for an appreciable time, and that both the oil and rope must be heated above the boiling point of water, and also that the immersion of the cable in the oil must be repeated at frequent intervals.

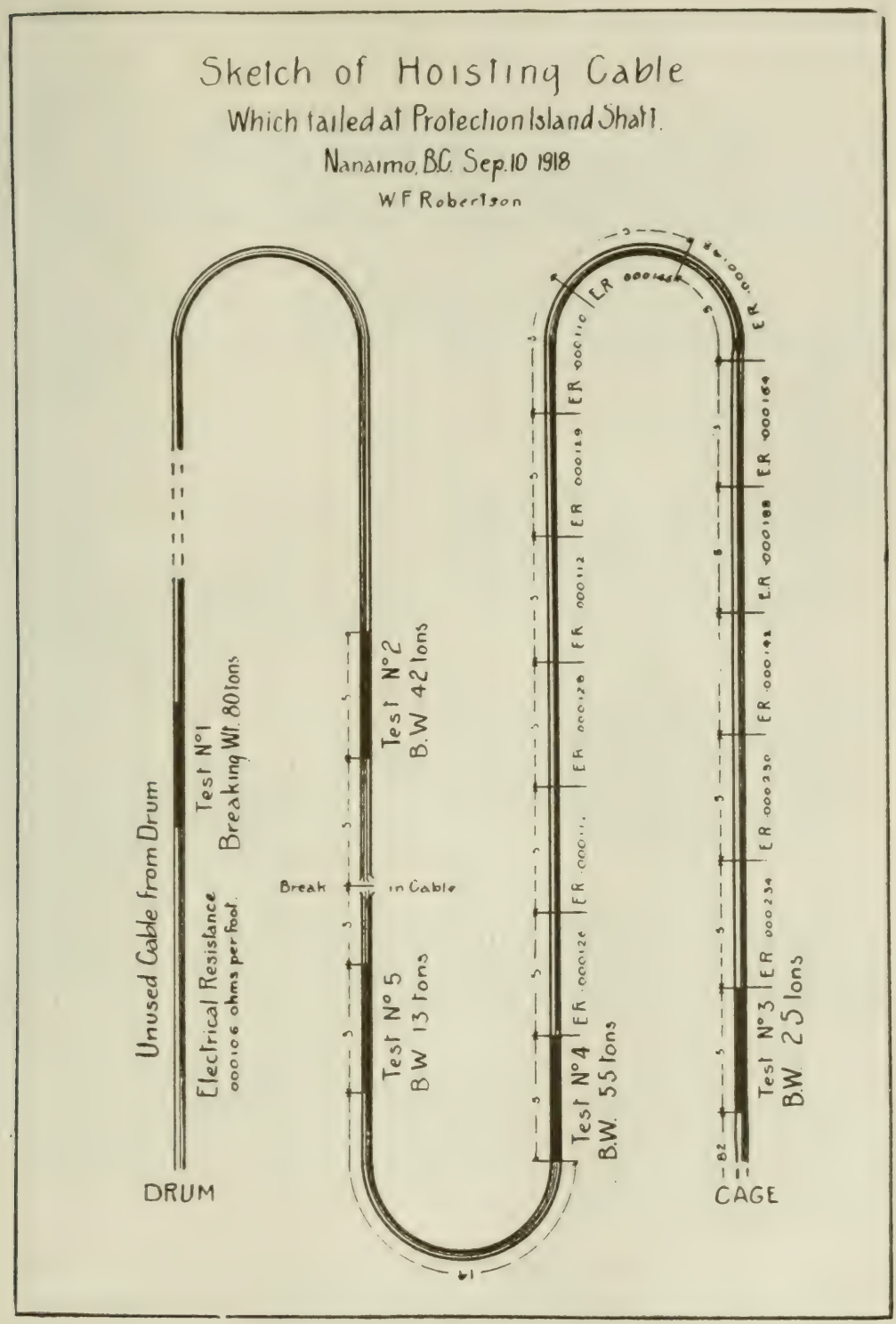
Mr. Ben Thayer of the Anaconda Copper Mining Company informed me that it was the practice of his company in Butte to pass the cables periodically through a bath of oil contained in a long trough heated with live steam. A mine manager, to whom I suggested this, replied, "If this is necessary, why do not the makers of the cable tell us to do it?" It may be news to the makers that they are supposed to supply such instructions with their commodities, but they might well take the hint.

A Method of Detection.

Observation of the fact that the pieces of cable tested had tensile strengths very approximately proportional to the sectional area of the wires remaining intact and unoxidized, brought back to me one of the few electrical principles remaining in my mind of the instruction I received many years ago at McGill, namely, that the conductivity of a wire is directly proportional to its cross-sectional area, etc., etc.

This suggested the thought that if we could test the conductivity of any suspected part of a cable as compared with a like length of a new unoxidized part of the same cable this ratio would give us, at least approximately, the ratio between the tensile strengths of the new and the suspected parts of the cables.

To test this theory I appealed to Mr. W. D. Fowler, of the electrical department of McGill University. I had with me a piece of the unused cable, and a length of 65 feet of the deteriorated cable which extended between test piece No. 3, with a tensile strength of 25 tons, and test piece No. 4, with a tensile strength of 55 tons. Mr. Fowler tested the unused cable and also tested the 65 feet of cable in sections of 5 feet each for electrical resistance, and his report is given in graphic form in the accompanying sketch showing the electrical resistance


Sketch of Hoisting Cable
Which failed at Protection Island Shaft.
Nanaimo, B.C. Sep. 10 1918
W F Robertson
Unused Cable from Drum
Test N°1
Breaking Wt. 80 tons
Electrical Resistance
.000106 ohms per foot.
Test N°2
B.W 42 tons
Break
in Cable
Test N° 5
B.W 13 tons
Test N° 4
B.W. 55 tons
Test N° 3
B.W 25 tons
DRUM
CAGE

found in the successive 5-ft. sections of the 65 feet of defective cable.

These tests were only approximate as the method of attaching the wires to the cable was imperfect, but they were close enough to show the theory to be substantially correct.

The tests showed the electrical resistances to be as follows:—

	Resistance in Ohms per ft.	
No. 1:		
Unused cable.....	.000106	
No. 2:		
Defective cable in 5-ft. length immediately adjoining test No. 4 having tensile strength of 55 tons.....	.000126	about 19% greater resistance than No. 1, the unused cable.
No. 3:		
Defective cable in 5-ft. length immediately adjoining test No. 3 which had tensile strength of 25 tons.....	.000234	about 120% greater resistance than No. 1, the unused cable.

These figures, while admittedly inconclusive, show such marked variations as to be quite sufficiently serviceable for detecting any dangerous internal destruction in a cable.

I have to present this suggestion in an incomplete form, but hope that some member who may have the facilities and opportunity to further investigate the subject experimentally, will do so, and I hope in the near future to be able myself to carry out further experiments.

The principle has a wide field of application to the standing cables of rope tramways, suspension bridges, etc., and quite possibly it may be found applicable to test the amount of cor-

rosion that has taken place in iron or steel members used in reinforced concrete structures where such are concealed from observation.

That a simple and rapid method can be devised to test cables seems probable from observing the rapidity with which a man tests the condition of connections at the rail-joints on the electric street railways with a small galvanometer wound in one direction for an equal length of rail, including the joint when, if the joint is as good as the rail, the galvanometer stands at zero. An enlargement of this appliance would be applicable for testing cables.

A SCHEME FOR OILING MINE CABLES IN PLACE.

By Wm. Fleet Robertson.

Annual Meeting, Montreal, March 1919.

In a previous paper I have had occasion to draw attention to and illustrate the destructive deterioration of certain wire cables that have come under my notice, due to the excessive rusting of the wires in the interior portion of the cable, while the exterior wires remained comparatively intact.

The explanation of this condition seems, without doubt, to be that the external wires were protected from oxidation by such scant lubrication as the cables had received externally, which, applied cold, failed to penetrate the core or the strands of the cable, leaving these unprotected from the corroding action of water and damp air.

The needs for oiling the interior of the cables are, first, to provide lubrication for the wires moving one on the other—although my observations have not shown any excessive wear on the wires from its absence—and secondly, and by far its most important function, to provide a protective covering for the wires to prevent oxidation.

My recent observations have been with relation to cables of 1¼″ and 1½″ diameter composed of steel wires formed into strands, these strands again being wound around a hemp core, which seems to be the accepted practice in the manufacture of cables of this size.

The internal hemp core when it leaves the factory is usually saturated with grease, which thus acts as a reservoir of lubricant for the wires of the cable, and lasts for some time, for, as a strain is put upon the cable, it compresses the core, thus expelling the grease between the wires.

In a comparatively short time, this 'reservoir' becomes exhausted of lubricant, its place being taken by air and water. It seems to be the accepted and logical conclusion that before the reservoir is depleted, that such should be promptly renewed,

if the cable is to be protected internally from oxidation and that such renewal must be repeated periodically.

How frequently this should be done will depend upon the conditions under which the cable is being used and would probably have to be determined experimentally.

The danger lies in the false assumption that a cable once lubricated internally always remains so, and in the only too-prevalent practice of trusting to the outward application of a little grease or oil, usually applied cold; that this will not penetrate the strands is a foregone conclusion.

It seems to be conceded generally that such penetration can most surely be obtained by the immersion of the cables for a certain time in the lubricant.

As to how this can best and most easily be accomplished has elicited numerous suggestions, one of which is the placing of the cable, coiled up, either off or on a reel, in a tank of oil for some hours.

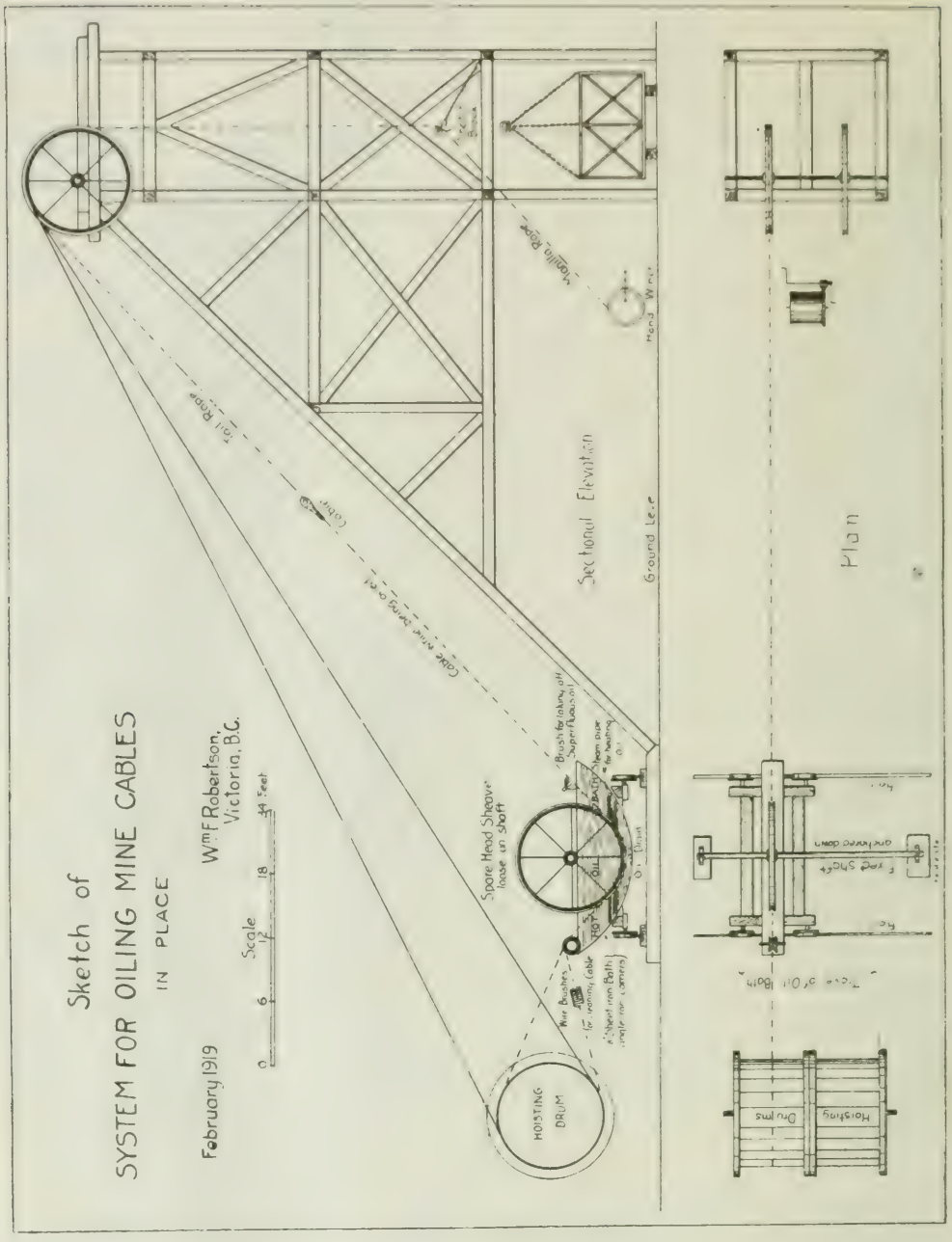
Some argue that this would be sufficient to be effective, while others demand that the tank be closed and its contents be subjected to pressure—175 pounds to the square inch being suggested—a rather serious and costly procedure.

A further suggestion is that the oil in the tank be also heated, and this last is, in the opinion of the writer, the only one which would be effective.

The interstices in the core and the strands, under working conditions, become filled with air and water, which cannot be driven out by the oil through pressure applied equally on all sides. Consequently, pressure alone would be ineffective, while as an adjunct to heat, it is superfluous and would be very expensive.

If the lubricant be heated to above 212° F. all water in the cable will be driven off as steam, while air would be so expanded as to be also expelled, and into the vacuum thus formed the oil would be forced by atmospheric pressure.

This tank treatment would probably be effective and is all


Sketch of
SYSTEM FOR OILING MINE CABLES
IN PLACE
February 1919
Wm F Robertson,
Victoria, B.C.
Scale
12
0
6
18
24 Feet
Sectional Elevation
Plan
Ground Level
Main Rope
Tail Rope
Cable
Cable Rope Drops Off
Spare Head Sheave
loose on shaft
HOISTING
DRUM
Holding
Dumps
Track for
Dumps

very well for cables as received and on reels, although not so necessary with new cables, as they are usually fairly well lubricated. If a renewal of the lubricating process is necessary, this would entail the removal of the cable from the shaft and from the drum, a coiling of it on a reel, and its transportation to and from the tank—a lengthy process during which the shaft must remain idle unless a spare cable is available.

The whole procedure represents such an expenditure of time and money as to not be favourably considered by the mine management.

To obviate this double expenditure and thereby insure that cables will be oiled and re-oiled the writer begs to present in the accompanying sketch an arrangement and plant which can be constructed cheaply from materials already around most mines, whereby a hoisting cable may be efficiently oiled without removal from the hoisting drum, without delay of more than half a shift and at a nominal expense.

The arrangement is fully shown in the accompanying sketch, which is very nearly self-explanatory, requiring but few words in addition.

The cage is brought to the surface, there blocked on timbers, the cable is detached from the cage and attached to a manilla, or other, tail-rope. The cable is then wound on the hoisting drum until the end of the cable and tail-rope come to the oil-bath.

The end of the cable is then detached and passed through the bath and under the sheave wheel; it is then attached again to the tail rope by which, with the aid of a hand-winch, the cable is slowly pulled through the heated oil-bath and back to the cage where it is re-attached and the empty cage slowly lowered to the bottom.

The operation is then reversed, the whole cable passing twice through the oil-bath.

About 16 feet of the cable would be in the bath at one time, and if the cable is passed through at a rate of four feet a min-

ute, it would then have two immersions of four minutes each, which it is thought, would be sufficient.

The oil in the bath must be kept at a temperature of over 212° F. by the aid of live steam pipes, and it is suggested that vaseline with flake graphite mixed through it, will probably be found to be most effective and lasting.

It is essential that the cable, before entering the bath, should be as thoroughly cleaned as possible of all dirt, by the use of wire brushes. The horizontal travel of the cable in unwinding will automatically move the bath and carriage on rails and so keep it in line at all times.

The supporting shaft of the bath sheave wheel must be anchored down sufficiently to hold the upward pull of the cable after the cage is attached.

DISCUSSION

MR. OLIVER HALL: In a discussion of internal corrosion of hoisting ropes attention should be called to the fact that Lang's lay ropes rust inwardly to a greater extent than ropes of the ordinary lay, largely because Lang's lay rope has a greater tendency to open up and allow the entrance of moisture. Generally speaking, ordinary lay rope is preferable for hoisting in shafts, and Lang's lay rope should be used for haulage purposes or slope hoisting, where the wear caused by the haulageway rollers affects mainly the life of the rope, and where corrosion is relatively unimportant.

MR. F. W. GRAY: I noticed the newspaper accounts of this accident, and appreciating its important significance had looked for further details but never saw any accurate account of the circumstances or heard of any subsequent action until now. It is pleasing and reassuring to know that this matter has been gone into so thoroughly. The paper states that the rope had been in use for three and a half years. That is a very long time, and apparently only a portion of the rope had been subjected

to use. The inspection of the rope, consisting as is stated of pressing through a glove to detect breaks in the outer strands, was certainly insufficient. The occurrence was one that demanded enquiry, and the thanks of the Institute are due to Mr. Robertson for bringing the important results of the investigation before its members, and for letting us know that the provincial authorities took the immediate action that so serious an accident called for.

THE USE OF EXPLOSIVES IN MINES

By H. Y. Russel

(Annual Meeting, Montreal, March, 1919.)

Probably it would be well at the outset to give a brief outline of the manufacture of explosives, as, in all probability, except by those directly engaged in their manufacture, less is known about the processes involved than about the manufacture of any other commercial product. This is not altogether due to the fact that any great secrecy is made of the processes, but rather because they are unusually hazardous and it is not desirable to expose more people than necessary to the dangers entailed. Consequently it is not the practice of explosive manufacturers to show people not directly connected with the industry through their plants. We believe, also, that it is the general opinion of the average layman that explosives are all the result of some chance discovery rather than the outcome of scientific investigations and calculations. The explosive chemist does not, ordinarily, accidentally develop or discover new compounds which are explosive. Rather, he sets out to manufacture a theoretical compound which he knows will be explosive, and what he discovers or invents is a commercial process for the manufacture of the compound desired. Practically all explosives are and have been formulated on paper and many of their characteristics determined by calculations before any of the actual explosives have ever been made. For this reason all up-to-date companies manufacturing explosives have large staffs of specially trained chemists whose duties are to test continually the raw materials that go into the explosive, the mixture of these ingredients as the process of manufacture develops, and the completed article.

The raw materials that go into the manufacture of explosives must be of a high commercial grade. They are bought upon certain standard specifications and, when received, they are tested under the supervision of the chemical division before being used.

The first step in manufacture is the examination and mixing of the 'dope,' or the material which absorbs and holds the

nitro-glycerine or the liquid explosive base. The composition of the 'dope' varies in different explosives, but it consists generally of soda. The constituent materials, whatever they may be, are first screened to remove any foreign bodies, and samples are sent to the chemical laboratory for analysis. If the necessary degree of purity is found, the materials go forward for manufacture; if not, they are rejected and properly purified, or, if that is not possible, they are discarded.

Each lot of satisfactory material is then thoroughly dried, to get rid of the excess moisture and afterwards grained and screened to insure each ingredient having its proper degree of fineness. These operations are of great importance, as any excess of moisture will have a very bad effect on the explosive, making it insensitive and apt to leak, while the screening not only removes small foreign bodies, such as pieces of stone, iron and steel, which would be a source of danger in subsequent operations, but the size to which the article is ground has a marked effect on the quality of the completed explosive. Samples of the dried and screened materials are tested by the chemists, and if satisfactory the different ingredients, with the exception of liquids, are put together in the proportions called for by the formula for the particular grade to be manufactured, and are run through a mixing machine which thoroughly mixes and then again screens them. The result is known as the 'dope.' This screening checks the first one and also removes any foreign matter that may accidentally have got into the ingredients since the preliminary screening.

Samples of the 'dope' are sent to the chemical laboratory in order that the proper incorporation of the different ingredients may be checked and analyses are made to prove that the proper proportions of the different ingredients have been used.

The 'dope' is now ready for mixing with the nitro-glycerine, or the liquid explosive. Each is carefully weighed to insure proper proportions being used, the 'dope' again screened and put into the mixing machine first, the nitro-glycerine being added and the apparatus started and worked until a thorough mixing

is accomplished. This completes the making of the explosive, and again the chemist checks up the results.

The explosives are then conveyed to the packing machines for punching into the paper shells. Different kinds of punching machines are used for nitro-glycerine and ammonia dynamites, and for gelatines (forcites). These machines are controlled as to the force of the punch they deliver and in this way the density of the cartridge and the number of cartridges to the case is largely determined and kept constant. This is checked every half-hour or so by weighing several cartridges, so that any variation in the density will be caught and the machine adjusted if necessary.

At times it is a rather difficult problem to maintain a constant density, as some of the ingredients vary considerably in this regard. This is particularly noticeable in ammonium nitrate, which is used extensively in 'Permitted Explosives' for coal mines, so that extra care has to be exercised in making up these explosives.

In calculating the formula for an explosive, particularly one for use in mining, where noxious fumes must be at a minimum, allowances of the oxygen-producing ingredients is made to cover the fume produced, even to the combustion of the waxed paper shell, and samples of the completed cartridges are sent to the works laboratory for final testing.

The packed shells, which are now called cartridges or sticks, are conveyed to the packing house. Those powders containing nitrate of ammonia, which is very hygroscopic, are dipped in a waterproofing compound in order to increase their water resisting and keeping qualities. The cartridges are then packed in the cases and weighed, and, in order to again check the density, the cartridges in every tenth or twentieth case are counted and the number required to make the net 50 lb. checked. Both during the punching and packing processes extreme care is taken to throw out all defective cartridges, which consist of torn shells or those partially filled. However, even though the

cartridges receive two handlings, it is almost impossible to insure against some cases containing a poorly packed cartridge here and there.

Before nailing the case, the packer inserts a slip bearing his number for reference purposes in case of complaints. It is thus possible, when complaints are accompanied by the packing slips, to trace the defect back to the packer. Besides the packer's slips the cases are marked on the outside with the month and year in which they were packed.

The analysis made at the laboratory is checked against the theoretical composition. Balistic pendulum and mortar tests are made for strength, and centrifugal tests for exudation. Sensitive tests are also made. Samples are also placed for observation in the magazines to see that the explosive will stand storage.

From the packing house the cases are taken to the magazine and stored ready for shipment. The magazines are so built as to insure their being dry and well ventilated, and stocks are piled so that the oldest will be shipped first.

All through the process of manufacture extreme care is taken in the handling of the materials and of the finished product to avoid the introduction of any foreign material, and the motto of the explosive manufacturer is that "Cleanliness is next to Godliness." This extreme care is also necessary in order to reduce the possibilities of an accidental explosion. Among the precuations taken may be mentioned the elimination, wherever possible, of all metal parts for containers and apparatus; where this is not possible, brass, bronze, or monel metal is used. All workmen are required to wear rubber-soled shoes, and are not allowed to wear clothes fastened with metal or bone buttons; nor are they permitted to have in their possession matches, jack knives, or any metal whatever. Employees are frequently searched during work to make sure these regulations are being obeyed, and any infraction means dismissal.

Rules are posted in every building, regulating the quantity of explosives permitted in that building at one time, the num-

ber of operators allowed, the methods of operating, the kind and number of tools permitted, and citing the necessary precautions to be taken to minimize the chance of accident.

As a safety precaution, the manufacture of explosives is carried out in several stages, each in its own house, and separated from the other buildings by a distance of 300 ft., each building being barricaded by mounds of earth extending up to the eaves of the building. These mounds are to prevent the lateral projection of missiles in case of an explosion in any of the individual buildings.

The above broad description of the manufacture of explosives will indicate the care and the safety precautions that are taken and also the very important part played by the staff of chemists who check up the different processes. To operate an explosive factory without chemists would be as impossible as to operate a mine and mill without assayers or assays.

The explosives discussed in this paper are those in which the explosive base consists of nitro-glycerine, nitro-glycerine in combination with gun cotton, or nitro-glycerine in combination with ammonium nitrate. They are known as 'high explosives' as distinct from blasting powders or low explosives.

It was not many years ago that users of explosives had a very limited variety to choose from; in fact blasting powder and one or two grades of N.G. dynamite covered the production. As to some of the old dynamites, anyone using them now would think they were going through a gas attack in which there were a considerable number of duds. The improvements in high explosives have been many, but they have been gradual, and they are due to the knowledge and ability of specially trained men. New explosive ingredients have been discovered, which, when added to nitro-glycerine, result in better and safer explosives, and the different steps in the manufacture are now under the supervision of experts, so that the finished product to-day is one that can be depended on for constant strength and reliability.

In the manufacture of high explosives, and in making improvements in explosives or producing new explosives, the

main points to be considered are, safety in use, strength, adaptability for certain kinds of work, stability, and cost.

The danger in the use of explosives is due to their liability to premature explosion upon receiving a sharp blow or shock; to leaking of nitro-glycerine owing to the use of improper absorbents or to exposure to moisture; to too high a thawing temperature; to defects in manufacture; or to their getting on fire and then exploding.

To lessen the possibility of danger from handling, ingredients other than nitro-glycerine are mixed with the N.G. and the result is an explosive of equal strength, but less sensitive to shock or fire. At the same time care must be taken that the sensitiveness is not so far reduced that the whole charge will not explode, thereby leaving unexploded powder in the drill holes or chamber.

In the case of straight nitro-glycerine dynamites, the marked strength shows the percentage of nitro-glycerine contained. Thus a 40% N.G. dynamite contains 40% by weight of nitro-glycerine; a 50% N.G. dynamite contains 50% N.G., and so on. With gelatines, such as forcite, and with ammonia dynamites, on the other hand, the marked strengths do not mean that they contain the marked amount of N.G., but that other explosive ingredients have been associated with N.G. in such quantities that, when used in similar weights, these explosives develop the same energy as an equivalent grade of straight dynamite, though with different velocities of detonation, etc., which make them better than straight dynamites under certain conditions.

The relative 'stability' of an explosive depends upon its ability to stand storage for a reasonable length of time without inclining to spontaneous combustion, losing strength, or otherwise deteriorating.

The principal explosives used in Canada to-day are nitro-glycerine dynamite; forcite (a gelatine dynamite); and ammonia dynamite. In the first the main explosive force is nitro-

glycerine alone; in forcite, it is nitro-glycerine and gun cotton; and in ammonia dynamite it is nitro-glycerine and ammonium nitrate. Before the war, explosives of the chlorate and nitro-starch classes were manufactured in Canada. These explosives were used to a certain extent, though they are not so strong as the higher grades of dynamite, forcite or ammonia dynamite.

N.G. dynamites, forcite and ammonia dynamite are made in two varieties, 'straight' and 'low freezing' or 'polar.' Nitro-glycerine explosives of the 'straight' variety, whether N.G. dynamite, forcite or ammonia dynamite, will begin to freeze at about 45° F. To overcome this as far as possible, 'polar' explosives are made. In polar N.G. dynamite the freezing point is lowered about 15°, so that it will begin to freeze at about the same temperature as water does. In polar forcite and polar ammonias the freezing point is lowered about 35°. The strength of the polar grades is the same as that of the straight grades. The exact freezing point of polar explosives is uncertain and subject to variation. They have been used without thawing on open work where the temperature ran from zero to 6° below zero for several days; they are known to have remained thawed after being exposed to a temperature of 10° to 15° below zero for over a week; again, they have been found frozen at a temperature of 8° to 10° above zero. From our experience in Canada we believe they will stand a temperature of from 10° to 15° above zero before freezing; and I could quote several cases where they have been soft, and were used without thawing after exposure for several days to a temperature below zero.

The advantages of a polar explosive in the spring, autumn, and winter are apparent for either mining or outside work. Their use does away with the necessity of thawing during five months of the year, when straight explosives have to be thawed. Almost anywhere in Canada polar explosives need not be thawed before the middle of November, nor after the middle of March, while with a straight explosive thawing should begin about the first of September and continue until the end of May, on account of the cold nights. Again, in some mines

the undergound temperatures are below 45° F., and straight explosives will chill and freeze if kept there any length of time, with the prospect, if used in this condition, of missed holes, burned holes, or partially exploded charges, which are both dangerous and expensive. Such powder must be returned to the thaw house and re-thawed. This does not happen with polar explosives. When polar explosives do freeze, however, they must be thawed in the same way as straight explosives.

While commercial high explosives of one kind or another are made in strengths of from 10 per cent to 100 per cent, there are certain limits which govern different forms. These limits may be determined either by railway shipping regulations or to the impossibility of manufacturing a satisfactory explosive above or below certain strengths. High explosives of less than 17 per cent strength are known as 'lifting powder,' 'railroad powder' (R.R.P.), or 'Judson powder,' and are used almost entirely in railway construction for large blasts.

Nitro-glycerine dynamite is made in strengths of from 17 per cent to 75 per cent, and is put up in cartridges 8 in. to 36 in. long and from $\frac{7}{8}$ in. to 5 in. diameter. Forcite (gelatine dynamite) is made in strengths of from 35 per cent to 85 per cent, in cartridges 8 in. or 16 in. long and from 1 in. to 5 in. diameter. Ammonia dynamites are made in strengths of from 30 per cent to 60 per cent, in cartridges from 8 in. to 18 in. long and from $\frac{7}{8}$ in. to 5 in. diameter.

While cartridges of the above lengths and diameters are made, the Bureau of Safe Transportation of Explosives places certain restrictions on the size of cartridges and on the percentage of nitro-glycerine allowed to be shipped 'by freight.' No explosive (except a gelatinized one) containing over 60 per cent N. G. can be shipped 'by freight'; also, explosives containing over 10 per cent N.G. (except gelatinized explosives) cannot be shipped 'by freight' in cartridges more than 8 in. long and 4 in. diameter. The reason gelatinized explosives are excepted is that they are not so likely to leak or to be exploded by shock as are the other brands.

High explosives are graded with a 10 per cent difference in explosive content, as, 30 per cent, 40 per cent, 50 per cent, and

60 per cent, and this grading has proved satisfactory to users of explosives. During the war the Canadian Explosives, Limited, at the request of the Government, in order to conserve raw materials and to assist customers to reduce costs, offered to make 35 per cent, 45 per cent, and 55 per cent strengths. These were tested quite extensively in some of the mines; in certain cases they were successful and are still used.

The energy developed by an explosive depends on the amount of gas liberated after explosion and on the temperature of the gas. The work done depends, in addition to the above, on the velocity of detonation, or the quickness with which the gas is liberated. Speaking broadly, the higher the velocity of detonation the more shattering effect an explosive has, and the lower the velocity of detonation the more heaving and less shattering the results. Considering equal grades, N.G. dynamite, on account of its high velocity of detonation, is the most shattering of the commercial explosives; then come ammonia dynamites, then gelatine dynamites or forcites. Velocity tests are made in the open as there is no way to make such tests with the explosive confined, as in a drill hole.

The tendency of users of explosives in Canada to-day, particularly in mining, is to use the lowest strength explosive that will break their ground when it is properly drilled. Until a few years ago considerable amounts of 'gelignite' (a 75 per cent N.G. explosive) were used in the mines of Porcupine, of Cobalt, and in British Columbia, but this has been replaced by 60 per cent, and often 50 per cent, explosives and a lowering of costs has followed. To-day by far the largest proportion of high explosives used in the mines of Canada is of 40 per cent strength, while little 60 per cent is used. This is due not only to the more careful supervision given to the use of explosives, but also to the fact that greater care is taken to see that the drilling is done properly.

In choosing an explosive for mining work the following considerations are important: Safety in use, breaking strength, minimum of injurious fume and smoke, and stability. It is also of advantage to use one kind and strength of explosive

throughout the mine. After these considerations come points such as non-freezing, plasticity (which allows the explosive to 'stay put' in a hole, filling it completely when tamped, so that it does not run out of an upper when the cartridges paper is split), and cost.

Until such time as the Dominion Government establishes a Department of Explosives with a testing station, the best a user of explosives can do towards deciding as to the safety or otherwise of an explosive is to take into consideration the standing of the company manufacturing the article from which standing he must judge how much weight can be attached to their assertion that the explosive is as safe to handle as it is possible to make it, and still have it explode when wanted.

In England, there is a list of 'Authorized Explosives,' that is, explosives which are authorized by the Home Office for use in work outside of coal mines; but in Canada this procedure has not as yet been followed, and the permission of the mine officials to test an explosive in any working rests mainly on the standing and reputation of the firm of manufacturers and the persuasiveness of the company's representative. A few facts, however, can be borne in mind. A gelatine dynamite, such as forcite, will give off less fume and smoke than either a nitro-glycerine dynamite or an ammonia dynamite. Moreover, being denser, more of it can be tamped into the bottom of the holes where the main work is to be done, and it will stand water and storage better than either of the other two.

Nitro-glycerine dynamite will shatter the rock more than the other two, and if there is a large amount of sand blasting or bull-dozing to be done, on account of not being able to pop-hole the large rocks, it is sometimes worth while to use it and have sufficient ventilation take away the fumes.

Ammonia dynamites are more gassy than forcite, but are cheaper and give more sticks to the case. They are worthy of consideration in a dry mine with good ventilation.

To test an explosive for breaking strength, fume, and smoke, a good deal of trouble and at times some expense must

be incurred, but both the trouble and the expense are very minor considerations if it is proved thereby that mining costs can be reduced and accidents prevented.

It is commonly considered that in drifting the ground is more difficult to break than in stoping, so that an explosive which will pull the drift rounds will be satisfactory in a stope. It is also more easy to judge the fume and smoke after a blast in a drift than in a stope, as the gases have not the same chance to disperse. An average drift, therefore, should be chosen for the test, and the best machine men in the mine should be employed to drill the rounds for testing the explosive. The standard round for the mine should be used and an official should examine each round before it is loaded, and note whether it is properly drilled or not, for it is evident that if a poorly drilled round breaks well, too strong and, therefore, too expensive an explosive is being used; while, if the break is a poor one, a notation that the round was poorly drilled may prevent the proper explosive from being condemned. A test of this kind should last from one to four weeks. The distance driven should be carefully measured and the cost of explosives per foot advance computed and compared with past records.

Testing for fume and smoke is usually done by entering the drift a reasonable, and sometimes an unreasonable, time after blasting, and seeing how close to the face one can get before the gas becomes too bad. This is neither comfortable nor safe. The best way is to wear a gas mask when entering the drift and then to take samples of the air at various distances from the face, and have them analyzed for injurious fumes. During the test care should be taken that the same ventilation is operating under the same conditions after each round of the test.

It should also be the duty of some official to see that the explosive is well thawed when used, that a careful record is kept of the amount used, and that the holes are well tamped. An explosive which is successful in a drift test can then be tested in stoping, and if satisfactory can be used throughout

the mine, with the knowledge that the best and most economical explosive has been adopted.

An explosive's stability, which is the quality that enables it to withstand storage in good magazines, as well as a reasonable temperature in a thaw house, without leaking or deteriorating, can be checked as the test proceeds.

Opening or developing a mine is done through a shaft or adit, and for this work a stronger explosive should be used than is necessary when a large amount of stoping is done. Not only are shaft-rounds particularly hard to pull, but the speed with which the mine has to be opened up makes a strong explosive advisable.

When the percentage of explosives used in stoping is much larger than that used in drifting or sinking, rather than employ two grades of explosives, a poor drifting or sinking round may be overlooked, but when speed is a large factor it is expensive and annoying to have badly broken rounds.

To use explosives economically, the following points must be carefully watched:

The explosive must be well thawed, not only before it goes into the mine, but when it is loaded into the holes.

Use strong blasting caps. The stronger the cap, the better and quicker the charge is exploded. More work is done, and slight defects, such as insensitiveness, due to chilling, freezing, or long storage, are overcome when using a No. 8 cap rather than a No. 6. While a No. 8 cap is more expensive than a No. 6, it contains double the detonating charge. In lead block tests the No. 6 shows an expansion of 755 per cent, the No. 8 of 1,215 per cent; or, when detonated in the lead block, the No. 6 enlarges the cavity from 2 c.c. to 17.1 c.c., the No. 8 from 2 c.c. to 26.3 c.c.

The explosive should be well tamped. At least one foot of stemming should be used; two feet is better.

All loading and blasting should be done by a blaster or a blasting crew.

Using frozen or insufficiently thawed explosive is not only wasteful, but dangerous, as not only does powder in this condition do from 15 per cent to 50 per cent less work than it should, but missed holes occur and unexploded powder is found in the bottom of the holes; both are a source of danger, the last especially.

When re-blasting is necessary it means, in most cases, either that the wrong kind of a round is being drilled; or that the round is improperly drilled; or that the wrong kind or grade of explosive is being used. Occasionally change of the rock is the cause, but the above-mentioned reasons apply in a great majority of cases.

Re-blasting old holes is very wasteful; the holes are enlarged at the top, and the rock is more or less cracked and shattered. It is frequently not much better than sand blasting or bull-dozing. If a close watch of the explosive consumption is kept at a mine which does much re-blasting, it will be found that from 15 per cent to 20 per cent of the explosive used in drifting goes for this work.

The use of good stemming will considerably increase the work done by explosives, and I think it is not too much to say that in mining work the increase would be 15 per cent. In other words, the load in a hole can be reduced from 7 sticks to 6 sticks if good stemming is used. With 40 per cent forcite at $25 per 100 lb. the saving is over 3 cents per lb.

While many of the larger mines have blasting crews it is rarely that the employment of a special blaster at smaller mines is thought worth while. This I think is a mistake. When this paper was written (December, 1918) the price of 40 per cent forcite at the mills was $25 per 100 lb. in carload lots of 360 cases or over. A mine could afford to pay a blaster $100 a month if he could save 30 sticks of powder a day; at the same time there would be a further actual saving in costs.

LIQUID FUELS—THEIR USES, PRODUCTION, CONSUMPTION, AND SOURCES, IN CANADA

By B. F. Haanel

(Annual Meeting, Montreal, March, 1919)

The ability to produce mechanical energy on an almost unlimited scale and with an efficiency scarcely dreamt of a few years ago is responsible for the creation and existence of this remarkable industrial age, and for the tremendous inroad made, during only a few years, on the very large stores of the natural resources of the earth. Without mechanical power, these resources, now being depleted at an alarming rate, would be of little service to mankind; hence one might say, without fear of contradiction, that 'mechanical power' is the foundation on which our civilization rests. And, since the principal sources of mechanical energy are the solid and liquid fuels, there is little wonder that the various nations of the world are endeavouring to take stock of the present and probable future supplies of these fuels, and are exhibiting an anxiety concerning some of them. Of all the natural fuel resources, petroleum is being exhausted at the most rapid and alarming rate, and it is for the future supply of this fuel that the greatest anxiety is felt.

The consumption of crude oil has increased to an enormous extent in less than two decades, on account of its utilization in a large and continually increasing field, for the generation of power through the media of the steam generator and steam engine, and the internal combustion motor, and for heating purposes in general.

The sources of this fuel, only a few years ago, were described as inexhaustible, and so far as the state of development of the methods for using this product at that time was concerned, the day of its probable exhaustion was so far distant that the term 'inexhaustible' could be employed in a broad sense. But to-day this term is not even loosely applied to any of the natural resources which cannot be replaced, and it is not necessary to enter here into statistical details for the purpose of showing how

the production and consumption of petroleum products have increased since the first commercial well was put down in the United States, about the year 1849. All should be conversant with such figures, and, though the annual increase alone in the rate of production of this commodity is sufficiently great to arrest the earnest attention of any engineer or technologist who has the interests of mankind at heart, the startling statement that the possible future supplies of crude oil in the United States will be entirely exhausted in twenty-five years, if the present rate of increase of production is maintained, will bring to the attention of even the most optimistic the real seriousness of the situation which is facing those responsible for maintaining and improving the civilization of to-day. And I would like to impress upon all those who are interested in not only the production and selling of this liquid fuel, but also in its utilization, the fact that liquid fuels are, as much as iron and coal, the pillars of this present-day civilization, and that the exhaustion of the present known sources, or the failure to discover new sources, of liquid fuel would be almost as fatal to future existence as the total exhaustion of either iron or coal. There are, no doubt, a few who will not agree with this statement, but to such I would suggest that an analysis of the relations existing between the industries dependent on iron and coal and those on petroleum will disclose many interesting and startling facts.

It is manifest that our civilization is now absolutely dependent on power in unlimited quantities, since the complex industrial and social systems which have resulted through its exploitation, on such a tremendous scale, have altered the lives and habits of the people to such an extent that its collapse would jeopardize their very existence. A luxury to begin with often, in time, becomes an actual necessity. Thus, our systems of transportation, especially the individual motor car and the industrial truck, might have at their birth been described as luxuries, but to-day such means of transportation as the world enjoys is an actual necessity. As a result of this exploitation of mechanical power, urban populations have increased enormously, and immense industrial plants have been located at logical points for

the distribution of the manufactured product and the reception of the raw material required. This has necessitated the establishment of centres for distribution of foodstuffs, etc., for the feeding of these thickly populated communities, separated in many instances by long distances from the sources of supply. The chaos which would result in this case, were the generation of power, through the failure of the required fuel, discontinued, can be easily imagined. This civilization must, therefore, continue to progress in its present direction until it perishes.

Uses of Liquid Fuels.—The pronounced improvements in the steam generator and steam engine, and the remarkable increase resulting in the quantity of energy developed by this prime mover, have opened up a wide field for the utilization of crude oil and its heavy distillate, known as fuel oil. These liquid fuels are to-day being used in very large quantities as the source of heat for generating steam for railway locomotives and steamships, on account of the efficient manner in which they can be converted into useful energy, the ease of handling and of firing, and the fact that a considerably larger quantity of heat energy can be stored in a unit volume than can be done with solid fuels. Practically all of the ships of the navies of the great Powers are to-day driven by power in some form, generated from oil, and the consumption of liquid fuels for this purpose alone will be greatly increased in the years to come. The invention, rapid development, and extended use of the internal combustion motor, all of which have taken place in very recent years, have produced an enormous demand for not only motor spirits (gasoline), but also, to a more limited extent, for the heavier petroleum distillates, tar oils, etc. An assured production of gasoline, on the one hand, and the increasing demand for internal combustion motors, on the other, have been the means for the creation of automobile and internal combustion motor works on an immense scale. Moreover, the organization of these most up-to-date works, which aim at the greatest economy in the construction of the motor car, from the purchase of the raw material to the finished product, has resulted in such reduced manufacturing costs that cars can now be purchased by

people who, a few years ago, looked upon them as a luxury to be enjoyed only by the wealthy. Thus, to-day, motor cars are being turned out by the hundred thousands. Great improvements have also been made in the internal combustion motor, both as regards reliability and efficiency. This increased efficiency, which makes it possible to travel more miles on a gallon of gasoline, together with the decreased cost of a car to the purchaser, has greatly increased the employment of the motored vehicle for not only pleasure, but for trucking and other purposes as well. So it will be seen that the efficient use of a commodity—in this case a liquid fuel—is not necessarily a means for conserving the commodity. On the contrary, the more efficiently a fuel can be used, and the cheaper the motor or apparatus for using the fuel can be obtained, the greater will the ultimate production and consumption of the fuel be.

This is one example where scientific achievement, coupled with engineering skill, tends towards the more rapid exhaustion of the natural resources. So far, then, as the exhaustion of natural resources is concerned, science and mechanical skill are far more powerful agents than waste and inefficiency for accomplishing such a result, which may appear to the non-technical man paradoxical.

Internal combustion motors, which in time will undoubtedly become the greatest consumer of the liquid fuels, are applied now not only to pleasure and industrial vehicles and motor boats, but in increasing numbers to aeroplanes, farm tractors and to individual power plants. Instead, therefore, of looking for a reduction in the demands for motor fuel oils, we shall have to expect and prepare for a continually increasing consumption from now on.

Liquid Fuels.—The liquid fuels produced and sold on the market for the production of power and generation of heat are: crude petroleum and its distillation products; light and heavy oils recovered during the carbonization of solid fuels containing a large percentage of volatile matter; light oils, gasoline, etc., recovered from casing head and other natural gases; crude oil

and distillates obtained from the distillation of oil shales; and, finally, alcohol made from vegetable products. These may be placed under two main heads:

1st.—Those obtained from deposits laid down in past geological ages.

2nd.—Those obtained from growing vegetable matter.

Under the first head are included the coal deposits, oil shales, natural gas and petroleum fields. The second head comprises such fuels as are manufactured from vegetable material.

The fuels of the first group represent the capital invested, inasmuch as they cannot be replaced when used. The fuels of the second group may be said to represent the interest on the capital, when the capital is represented by the sun and the elements of the soil. Hence, this source of liquid fuels is continuous, and inexhaustible when proper care is exercised in the method of growing the vegetable matter. These, in short, are the sources of the various liquid fuels, but by far the most important sources at the present time are the petroleum fields and the oil shale deposits.

Consumption of Liquid Fuels in Canada.—The requirements of Canada for crude and refined oil products during 1917 amounted to 387,000,000 imperial gallons (approximately); 1,601,368 imperial gallons of alcohol, ethyl, methyl, etc.; a certain quantity of benzol, and grain alcohol, spirits, etc., to the value of approximately $2,000,000.

The total quantity of crude and refined oil products which was imported into Canada during 1917 amounted to 378,224,746 imperial gallons, and represents a value of $21,239,347. The imports included: crude oil for refining, 183,105,102 gallons; petroleum and gas oils, 142,455,582 gallons; illuminating oils, 13,457,096 gallons; lubricating oils, 5,315,811 gallons; gasoline, 15,369,172 gallons; and other oils, products of petroleum, 18,521,983 gallons.

About 199,000,000 gallons of crude oil were reported as used in the Canadian refineries—191,000,000 gallons imported

oil, and about 8,000,000 gallons of crude oil of domestic production. From this quantity of crude oil it is also reported about 54,000,000 gallons of gasoline and motor oils were obtained.

According to American practice, about 12-15 per cent of gasoline is obtained from the crude oil by the employment of the method of dry distillation.

In 1914, for example, 191,262,724 barrels of crude petroleum were used in 176 establishments in the United States, comprising crude oil from all of the producing fields, and the quantity of naphthas and lighter products, gasoline, recovered amounted to 23,908,242 barrels. This represents a gasoline recovery of about 8 per cent.

The average yield of products by dry-distillation when a paraffin-base petroleum is used is:

Light naphtha Heavy naphtha	12 to 15 per cent.
Burning oil stocks	65 to 75 per cent.
Tar	10 to 12 per cent.
Loss	5 to 6 per cent.

The term gasoline is applied to the light and heavy naphthas. In the destructive distillation of a paraffin-base petroleum, the first collection—light naphtha—is made between 80° Baume to 69° Baume. The second collection—heavy naphtha—is made between 69° to 58° Baume.

The Burton process is now being used on a large scale for the production of gasoline. Up to 1916, this was the most efficient cracking process in commercial use, and the same statement probably holds to-day. The product obtained by the Burton process is sometimes termed 'Motor Spirits.' According to Bulletin No. 114 of the U.S. Bureau of Mines, the quantity of gasoline produced by the Burton process in the United States during 1915 was 3,000,000 barrels, which it is further stated is equivalent to 18,000,000 barrels of mid-continent crude oil (an average paraffin-base petroleum), consequently only about one-sixth of the bulk of such a petroleum was converted into

gasoline—in other words, the gasoline recovery amounted to about 17 per cent. According to the best American practice, which there is no reason to believe is improved upon in the Canadian refineries, the quantity of crude oil, viz., 199,000,000 gallons, should have yielded about 33 million gallons of gasoline or motor spirits instead of 54,000,000 gallons, as reported to the Chief of the Division of Statistics of the Mines Branch, Department of Mines, by the various Canadian refineries. The average gravity of the Burton product is 60° Baume, while the mean gravity of a large number of samples of gasoline received from Canadian refineries, and tested in the Mines Branch Laboratories, is 60° Baume. The discrepancy in the above returns of gasoline produced in Canada cannot, therefore, be accounted for by a difference in gravity.[1]

Consumption of Crude and Refined Petroleum.—During the period 1910 to 1916 inclusive, the imports of crude and refined petroleum products rose from 84,629,000 gallons to 292,426,000 gallons, while the domestic production of crude petroleum dropped, during the same period, from 11,156,000 gallons to about 7,000,000 gallons. The imports of gasoline increased from 17,000,000 gallons in 1910 to about 41,000,000 gallons in 1912, and then steadily dropped to 18,000,000 gallons in 1916. The production of gasoline in Canadian refineries, on the other hand, steadily increased from 4,000,000 gallons in 1910 to 60,000,000 gallons in 1918. The gasoline requirements for all purposes during 1918, therefore, amounted to 69,000,000 gallons. The Canadian production of crude oils, it will be seen, amounts to only two per cent of the imports. To this production may be added a comparatively small quantity of benzol and light oils derived from two by-product recovery coke oven plants, situated at Sault Ste. Marie and in Nova Scotia. This quantity may not be more than one and a half million gallons.

The uses for crude and refined petroleum products are multiplying at a remarkable rate; not only is there a continually increasing demand for motor spirits for motor cars and trucks

[1]An explanation of the record is being sought by the Division of Mineral Resources and Statistics of the Department of Mines.

of all kinds, but for farm tractors and farm machinery generally, and as a result of the past four years of war we now have to make provision for supplying aeroplanes in increasing numbers for both national and private purposes.

It is good policy, therefore, to make enquiries now concerning our available sources of liquid fuels and to make every effort to place Canada, as regards her requirements for this commodity, on a self-supporting basis, or at least render her much less dependent on outside sources than she is at the present time.

I have dealt in some detail with the oil industry in the United States merely to show what is being accomplished in the country that supplies over 60 per cent of the world's crude and refined petroleum products, and also for the purpose of creating the suggestion that the requirements of the United States for liquid fuels will become so great in the near future, that Canada's increasing requirements for these fuels will have to be met from some other source. In other words, it appears to me, the time is at hand when the people of this country must make an energetic search for sources of liquid fuels and develop to as full an extent as economic conditions will permit the sources at present known to exist.

Sources of Liquid Fuels in Canada.—So far I have only considered petroleum and its products, because by far the greatest proportion of the liquid fuels used for power and heating purposes has been derived from this source, all other sources contributing but a small fraction of the total production and consumption. In a country, however, where great producing oil fields do not exist or where such fields have not yet been discovered, other sources will have to be investigated with a view to determining the commercial feasibility of their exploitation; and when such a country finds itself in this position the development of the known sources of oils will have to be vigorously prosecuted whether handsome profits are possible or not. It is, of course, impossible to expect such developments to take place if the best that can be promised is a loss on the capital invested.

Canada is a country precisely in that position. Her oil fields which can be said to be of economic value are of limited

extent, and the principal oil producing fields, moreover, are rapidly decreasing in productivity. The newly discovered fields, on the other hand, have not come up to expectations, and to-day cannot in any sense be termed as large producers.

The total production of crude oil (petroleum and light oils) during 1917 amounted to 8,480,000 gallons. This production, according to the Chief of the Division of Mineral Resources and Statistics, is about 7,000 barrels greater than in 1916, but less than the production of any other previous year for which records are available. This statement is significant when the demands for petroleum and its products during the past four years are taken into consideration.

Of the total production of Canadian crude oil, Ontario supplied 202,991 barrels; New Brunwsick, 2,341 barrels (all of 35 gallons each); while Alberta supplied 294,000 gallons of gasoline and refined illuminating oils. It is clear that our requirements cannot be met by the present rate of production of our known and developed oil fields, and the future only will disclose what may be expected from new oil fields which it is quite probable may be discovered.

The sources of oils, and other liquid fuels to which we shall, therefore, have to direct our attention are: the oil shale deposits of New Brunswick, Nova Scotia, and elsewhere; the high volatile solid fuels; possibly gasoline recovered from casing head gas and other natural gas; and last, but of very great importance, the manufacture of alcohol from vegetable matter.

Oil Shales.—Notwithstanding the fact that a flourishing oil shale industry has existed in Scotland for many years, and that this industry has yielded handsome profits despite the comparatively low oil yield of the shales utilized, Canada, though dependent on foreign sources for her oil supply, has failed, up to the present time, to develop an oil shale industry. While it is well known that extensive deposits of rich oil shales exist in Canada—notably New Brunswick and Nova Scotia—no estimates concerning the tonnage suitable for retorting or the average oil contents of the various deposits are available. It is

consequently impossible to even approximate the quantity of oil which is lying dormant in these deposits.

Interest in the possibilities of a Canadian oil shale industry has been manifested by many prominent parties, and on several occasions actual steps were taken to form companies for the exploitation of certain of the New Brunswick shales with a view to the establishment of an oil industry. But all such efforts failed of their ultimate object, and although incorporated companies, possessed of the requisite charters, and shale deposits suitable for the recovery of oil on a profitable basis, are still in existence, there is no oil shale industry in Canada to-day.

Several reasons might be advanced for this apparent lack of enterprise, especially at a time when oils suitable for refining are in such great demand, but in this paper I shall refer to only one, viz., failure to enlist the services of those who are in a position by education and long experience properly to advise as to the methods to employ both in winning the raw material and treating such material for the recovery of oil. Those who are qualified to express opinions regarding the retort or retorts to employ, the methods to be adopted in refining the crude oil and, in general, to recommend the policy to be adopted governing the entire undertaking, are naturally the oil engineers, who have been and are to-day closely identified with the Scotch oil shale industry. Engineers, no matter what their qualifications may be, who have not an intimate working knowledge of the oil shale industry as conducted in Scotland, or who have not acquired the requisite knowledge by actual experience, either through association with other oil shale concerns, or by experience gained through experimentation on a practical scale with oil retorts of various designs, are not competent to advise or express opinions, concerning the establishment of an oil shale industry in this country. The establishment of a successful oil shale industry in New Brunswick or elsewhere is not contingent on the discovery of the principles on which the successful retorting of oil shales is based, nor has it been held back because of a lack of a suitable retort. The technology of retorting oil shales is thoroughly understood to-day, and the evolution of the

retort employed has been going on for many years. Moreover, retorts of various designs, embodying many ideas, have been constructed and thoroughly tried out, and of these retorts the most promising have been retained and improved upon—improvements resulting from the working knowledge gained by actual practice. Hence, nothing is lacking for the successful inauguration of a Canadian oil shale industry.

If the desire to attempt to improve upon the existing processes and methods for retorting oil shales becomes too great —for those who are labouring to utilize our oil shales—to resist, it is well for them to bear in mind that the first essential is the establishment of the industry itself on well tried lines. When this has been accomplished and the enterprise has become a profitable business, the desire to improve any portion or the whole of the process might be contemplated, but not even then by anyone except a most competent and thoroughly qualified engineer, one who has grown up with the industry. Chemical engineers do not spring into being like the dragon-fly overnight, nor when once born and fully developed and recognized as qualified engineers do they as rapidly fade away. It is well in the oil shale industry, as well as all other industries of to-day which have to exist on a close margin—where a few cents one way or another may mean success or failure—to remember that such industries are not schools for the purpose of educating lawyers, doctors, merchants, or others widely separated from the legitimate field of the engineer, to become oil or other varieties of engineers.

In the year 1917, 3,117,658 tons of oil shales were retorted in the British Isles, with an average yield of 20 gallons of oil per ton. Thus, over 60,000,000 gallons of oil were produced in this manner. The recovery of sulphate of ammonia amounted to 20 lb. per ton of shale, so that for the above tonnage of shale the quantity of sulphate of ammonia recovered would be about 60,000,000 lb. At this point it will be of value, as well as of interest, to quote the summing up of the present facts

regarding the oil shale industry, by Victor C. Alderson, President of the Colorado School of Mines:

"1. The oil shale industry has reached its greatest development in Scotland, where it was established in 1850. Next in importance comes France, and then New South Wales.

"2. In Scotland the technical and chemical problems of the industry have been carefully solved, and on the whole the industry has been commercially profitable.

"3. The Scotch shale beds are comparatively thin, irregular, steeply inclined, deep, and expensive to work.

"4. The oil content of the Scotch shales is now much less than formerly, and the shale could not be worked profitably if it were not for the ammonium sulphate produced as a by-product.

"5. The production of crude oil alone from shale probably cannot now compete commercially with oil from wells. However, the increased demand for oil, the decreasing production, the steadily enhanced price on the one hand, will be met by an almost inexhaustible supply of oil shale, cheap mining, improved methods of distillation and valuable by-products, which will undoubtedly in the very near future make the oil shale industry a strong competitor of the flowing well and in the by no means distant future its successor.

"6. The oil shale industry is not in ordinary parlance 'a poor man's game.' The technical and chemical problems are numerous and require a high grade of scientific ability for their solution.

"7. A plant of 500 tons daily capacity is as small as can be operated permanently and successfully, as the profits will depend chiefly on the large tonnage handled. In this respect the oil shale industry bears the same relation to oil that Utah copper and the other copper porphyries bear to copper.

"8. An investment of $150,000 is as small as can be safely counted upon to make a single project successful."

Particular attention is directed to clause 4, viz., "The oil content of the Scotch shales is now much less than formerly, and the shale could not be worked profitably if it were not for the ammonium sulphate produced as a by-product." In this connection it will be interesting to compare the yields obtained from 41 tons of New Brunswick shales which were passed through the experimental retort at the Pumpherston Works, Scotland. The total yield of oil was 1,473 gallons, average 40 gallons per ton; average yield of sulphate of ammonia, 76.94 lb. per ton. If this shale which was sent to Scotland for testing represents the average shale of New Brunswick, the chances for a profitable oil shale industry in that province are indeed very bright, since both the oil and ammonia yields are twice as great as that of the Scotch shales. The Scotch shale industry, it is true, has cheaper labour in its favour, but the greater yields of oil and ammonia possible with the New Brunswick shales should more than offset that.

Crude Scotch shale oil has a specific gravity of from 0.860 to 0.890, and has a dark green colour. On refining, it yields approximately:[2]

Naphtha (motor spirits)	6	per cent
Burning oil	32	" "
Heavy oil	24	" "
Paraffin scale	12	" "
Loss	26	" "
	100	" "

While many samples of Canadian oil shales have been analysed and their oil content determined, the recovered oil has never been fractionated. The results of such a fractionation, however, would not be dissimilar to those of the Scotch shales.

High Volatile Bituminous Fuels.—The source of oils of next importance are the bituminous fuels of high volatile content.

[2]Liquid and Gaseous Fuels. Vivian B. Lewes, p. 97.

These include bituminous coals, coking and non-coking, lignites and peat.

When a bituminous coal is carbonized in a retort, the volatile matter is drawn off as condensable and non-condensable gases, tar vapour and moisture, and a residue composed of practically pure carbon and an ash consisting of the mineral matter of the coal remains in the retort. This carbonization may be conducted at high or low temperatures, depending on the product or products desired. High temperature carbonization is resorted to when the main product is coke, e.g., metallurgical coke. The gaseous products, consisting of the condensable and non-condensable gases and tar, aqueous and ammonia vapours, are in this case termed by-products. A high temperature is also employed when the main product sought is a gas for domestic or other purposes (town gas).

When, however, the maximum of oils, ammonia, tar, etc., and carbonized residue, but a minimum of non-condensable gases, are desired, a low temperature is employed.

At the present time, carbonization of bituminous coal is practically confined to the manufacture of metallurgical coke and town or retort gas. The production or recovery of oils suitable for fuel purposes is, therefore, confined to those coking or gas making plants equipped with by-product recovery apparatus.

The growing scarcity, however, of anthracite coal has created a demand for a fuel suitable for domestic purposes, and, as a result, a large amount of research work has been done during the past few years, both in England and the United States, concerning the carbonization of bituminous coals at low temperatures. In the United States, activity in this direction has been very pronounced, especially during the past four years. One plant is now in operation, and others are under construction for the low temperature carbonization of bituminous coal. The process employed permits of the maximum recovery of oils and other by-products and of a carbonized residue for briquetting

into a fuel eminently suitable for industrial and domestic purposes.

Benzol and its Homologues.—The principal liquid fuel resulting from the carbonization of a bituminous coal, either in by-product recovery coke ovens or in retorts employing low temperatures, is benzol and its homologues, toluol and xylol. The quantity of light oils recovered from the gas resulting from the carbonization of one ton of coal varies according to practice, and with the composition of the coal. But the recovery of 2½ gallons of light oil from the gas of one ton of coal carbonized, and one-tenth gallon from the distillation of the resulting tar, is considered by certain authorities as representing the average results of American practice, and this figure will be taken as representing Canadian practice.

The total yield of tar, in the case of one low temperature carbonization process (invented by Charles H. Smith) from a coal containing 35 per cent volatile matter, is 30 gallons water-free tar per short ton. This tar contains approximately 30 per cent pitch and 70 per cent of tar oils. The fractionation and subsequent treatment of the tar oils give 1.8 to 2.2 gallons of motor spirits (or c.p. benzol, 0.250 gallons; c.p. toluol, 0.500 gallons, motor spirits, 1.00 gallons), in addition to a large quantity of crude taracids, naphthas, creosote oils, pitch, gas, and 20 lb. of sulphate of ammonia per short ton of coal carbonized. To the above quantity of motor spirits obtained from the distillation of the tar must be added about 2½ gallons (American) of benzol obtained by stripping the gas. This will make the total yield of motor spirits for one ton of coal, carbonized, 4.3 to 4.7 gallons.

The quantity of coal coked in Canada during 1918 was 1,928,928 short tons, but only a portion of this total was coked in by-product recovery coke ovens. If, however, the entire quantity were carbonized in recovery ovens, the yield of motor spirits on the basis of 2½ gallons per ton of raw coal carbonized would have been only 4,800,000 imperial gallons, and about six gallons of tar per ton, or 11,400,000 gallons. Since the recovered motor spirits would be mainly used as a substitute

for gasoline in motor cars, it will be interesting to see just to what extent such a recovery would affect the imports and production of gasoline.

In 1918, 273,874 motor vehicles were registered in Canada, and assuming that the average consumption of gasoline per car for that year was 200 imperial gallons (which would give 2,000-3,000 miles per car), the total requirements of motor spirits for this purpose alone would be over 54,000,000 gallons. It will, therefore, be readily seen that the possible recovery of benzol, viz., 4,800,000 gallons, which represents only a small fraction of the gasoline requirements, would supply, on the above basis of mileage, less than 24,000 cars.

The quantity of coal carbonized, or which can be economically carbonized in coke ovens, depends on the demands for the carbonized residue. There is, therefore, a limit to the production of motor spirits and oils from coal. If, however, as is quite possible, our imports of anthracite coal were replaced by briquettes made from carbonized bituminous coal, some 5½ million tons of coal would be required, and the yield of motor spirits would then be, including that obtained from the coking of approximately 2,000,000 tons of coal for other purposes, about 29 million imperial gallons. This, however, would appear to be the maximum quantity of coal which could be economically treated in this manner for some time to come.

Benzol is entirely suitable for motor purposes when mixed with the higher hydrocarbons, and in moderately warm weather can be used successfully by itself. Benzol has a tendency to freeze at comparatively moderate temperatures.

Natural Gas as a Source of Gasoline.—The natural gas of many localities contains gasoline vapour, and other volatile hydrocarbons, to such an extent that its recovery on a commercial basis is possible. Large quantities of gasoline are being produced from this source in the United States, and the annual production is continually increasing.

The gasoline recovered in this manner in that country is of greater importance as regards quantity than the motor spirits

recovered from the dry distillation of coal. In 1915, for example, 65 million gallons of gasoline were extracted from natural gas, while in 1916 the production was more than 100,000,000 gallons, a very remarkable increase.

Two principal methods are employed for the extraction of the gasoline vapour: the absorption, and compression and refrigeration or condensation methods.

According to the results of investigations which were carried out by the Bureau of Mines of the United States with a view to ascertaining the suitability of the gas of various fields for the manufacture of gasoline according to the above processes, the compression and condensation method can only be profitably employed for the extraction of gasoline from casing head or 'wet' natural gas that contains more than one gallon of gasoline per 1,000 cubic feet, whereas both casing head gas and 'dry' natural gas containing a much smaller quantity of gasoline (one or more pints) can in many cases be profitably treated by the absorption method.

The compression and condensation method, which depends upon the theory of precipitation of vapours from natural gas, is comparable to that of water vapour from the atmosphere. Condensation of these vapours is effected by compression and by cooling. The absorption method, on the other hand, depends upon an entirely different physical property, viz., that of the solubility of vapours in liquids. With this method the gas is brought into contact with an oil which dissolves or absorbs the vapours, and the vapours are later distilled from the oil, and condensed. This method is analogous to the method employed for recovering benzol from coke oven gas (termed stripping).

Many factors, however, must be determined before natural gas can be effectively treated by either of these processes, or a combination of both. The quantity of gasoline vapour present in the gas is not always the deciding factor. A knowledge of the history of the field is necessary in order to determine the probable life of the wells, and the character of the sand from which the gas is produced is a valuable factor in designing a

plant. In all cases it is necessary to determine the volume and gasoline content of the gas from the field under consideration. Other factors are water supply, transportation facilities of both the gas pipe line and the finished product and for the blending liquid. Gasoline extracted from natural gas by the compression-condensation method is always blended, i.e., mixed with some heavier straight still-run refinery distillates to reduce the losses due to weathering of the unblended condensate. The losses resulting if the condensate is not blended range up to 75 per cent when it is allowed to weather until its vapour tension is reduced to less than 10 lb. at 100° F. and its temperature rises to that of the atmosphere. By proper blending, the losses are reduced to half this amount. Naphtha is the fluid generally employed for blending. It is important, therefore, when considering the erection of a plant for manufacturing gasoline from natural gas, to ascertain the quantities of blending fluid required in the case of the compression and condensation method, and of the oil required for absorbing the gasoline vapours when the absorption method is employed. In plants of large capacities the quantities of both of these oils will be large, especially when the compression method is employed, since the blend is mixed with the condensation and is sold with it to the consumer. The oil used for absorption, however, is used over and over again, and only sufficient oil to make up losses need be considered after the original oil has been obtained.

Canada possesses extensive natural gas fields, especially in its western portion, but only very approximate estimates regarding the quantity of gas available, in the developed fields, can be made. Certain of the areas which have been developed, or are undergoing development, very probably produce a gas which can be profitably treated for the extraction of gasoline. But up to the present time information concerning the quantities of gasoline vapours present is not sufficient to enable one to venture an opinion which would be of any value; and other factors on which the establishment of an industry of this kind depends have not yet been sufficiently investigated to warrant even the roughest estimate concerning the value of our gas fields for the

manufacture of natural gas gasoline. There are, however, great probabilities that Canada possesses in her natural gas fields an economic source of motor spirits.

Alcohol from Vegetable Products.—Notwithstanding the immense stores of crude oil, light oils contained in natural gas, and even the oils which can be obtained from the carbonization or retorting of high volatile coals, the fact remains that the greatest source of liquid fuels is our forests and agricultural fields. This source may truly be described as inexhaustible, when mankind exercises the proper intelligence in the growing and reaping of the crops, whether they be timber, grain, or vegetables. And the time will surely come when this will be the only source. The liquid fuel obtained from vegetable matter is alcohol, and concerning this fuel it has been said that the two most important chemical compounds known to mankind are "Water and Alcohol."

The principal sources of alcohol in Canada at the present time are waste wood resulting from lumbering operations, waste sulphite liquor produced in the manufacture of sulphite pulp and grain.

Alcohol from Waste Wood Products.—The wood waste produced in lumbering operations is exceedingly difficult, if not impossible, to estimate with any accuracy, since statistics relating to this phase of the lumber industry in Canada are not obtainable. Such waste includes the sawdust produced in sawing the logs into lumber, and shingles, the shavings from the planing mills, and bark slabs and shorts, which cannot be sold or utilized as lumber, but are usually burned in the incinerator as rubbish, or under boilers for the generation of steam for power or other purposes. The statement, however, is made,[3] that at Fullerton, La., the mills of the Gulf Lumber Company cut about 300,000 board feet of lumber per day, yielding some 600 to 700 tons of refuse of all kinds, and that the lumber waste destroyed by the coast mills in British Columbia alone amounts to approximately 10,000 tons per day. On the basis of the yield of refuse

[3]Alcohol from Wood Waste, by George H. Tomlinson. *The Canadian Chemical Journal*, p. 115, May, 1918.

in the Gulf Lumber Company, viz., 600-700 tons per 300,000 board feet of lumber cut, the refuse produced in the lumbering operations of Canada, when 3,489,550 thousand feet B.M. were cut in 1916, would amount to about 1,164,000 tons. According to the estimate of waste in British Columbia lumbering operations, the waste for that province alone, assuming a working year of 300 days, would amount to 3,000,000 tons. This estimate is evidently wrong. For the purpose of estimating the quantity of alcohol which could be produced by using a well-tried and commercial process, the smaller figure will be used, viz., 1,164,000 tons. From this quantity of wood 29,000,000 gallons of molasses, assuming a 50 per cent moisture content, or 14,500,000 gallons of alcohol, could be manufactured; and the residue left after the extraction of the sugar, which amounts to 70 per cent of the original material, could be used for the production of power.

Several plants have been erected and are (in 1918) in successful operation, utilizing the wood waste of lumber mills. The product obtained is ethyl alcohol, and requires to be denatured before it can be utilized for industrial purposes.

Waste from Lumbering Operations.—According to J. S. Bates, Superintendent of the Forest Products Laboratories of Canada, no ethyl alcohol is manufactured from wood products in Canada at the present time. He estimates: the forest waste approximately 25 per cent of the tree; the saw-mill waste approximately 40 per cent of the tree; lumber approximately 35 per cent of the tree; which makes the waste equal to the production of lumber.

For the purpose of estimating the quantity of alcohol it is possible to make from this raw material, Mr. Bates makes the assumption that the sawdust and waste suitable for making into 'hogged waste' would equal one-half the waste.

The total lumber production, using his figures, from soft woods in 1915 amounted to 3,632,630,000 board feet.

1,000 board feet lumber (oven-dry) has a volume of 83.3 cu. ft. and will average 30 lb. per cu. ft., approximately 2,500

lb. oven-dry wood per 1,000 board feet. Consequently, the quantity of oven-dry waste available for alcohol would be:

$$\frac{3{,}632{,}630{,}000}{2\times 2{,}000}\times\frac{2{,}500}{1{,}000}=2{,}300{,}000 \text{ tons.}$$

and, on the basis of a yield of 15 imperial gallons of 95 per cent alcohol per ton of oven-dry wood, the production for Canada would amount to 34,050,000 imperial gallons.

In regard to the above estimate, Mr. Bates makes the following statement: "There must be taken into account, however, that these totals do not mean much. Alcohol plants must be located close to supply and markets. There must be a continuous operation of alcohol plants, and this implies a large and continuous supply of waste wood, which would eliminate many waste wood possibilities. It is estimated that 1,500 gallons of alcohol per day is the minimum for an efficient plant, and for this production 100 tons of waste wood per day would have to be available."

Notwithstanding the obstacles which at present appear to block the utilization of the enormous quantity of waste, the waste wood of lumbering operations does constitute one of the most important and valuable sources of industrial alcohol, and necessity will find some way for its profitable utilization for this purpose.

Waste from Production of Sulphite and Sulphate Pulp.—The production of pulp in Canada during 1918 amounted to 550,836 tons sulphite, and 190,000 tons sulphate. Since all organic matter is destroyed in sulphate and soda liquors, sulphite liquors, only, need be considered as a source of alcohol.

One ton of sulphite pulp produces approximately 10 tons (2,000 imperial gallons) of total waste liquor, which by simple draining is reduced to five tons (1,000 imperial gallons), i.e., only about one-half is recovered. According to this statement, then, the quantity of waste liquor available for the manufacture of alcohol is 550,000,000 imperial gallons. The total sugars

average about two per cent of the liquor, and of these about 65 per cent (or 1.3 per cent of the liquor) is fermentable; consequently the yield of 95 per cent alcohol by volume would be approximately seven imperial gallons per ton of sulphite pulp produced, or approximately 4,000,000 imperial gallons for the total production of sulphite pulp for 1918. Estimates of cost, both of production and of selling, have been made by various persons, but since these are more or less misleading they will not be quoted here, inasmuch as such statements involve considerable detailed explanation. Sulphite liquor is a valuable source of industrial alcohol, which can be utilized immediately, in so far as a workable process, the quantity of waste liquor, and conditions of manufacture are concerned. At the present time, the high tax placed on alcohol would make such an enterprise entirely unprofitable.

In 1912, Sweden manufactured 5,800,000 gallons of absolute alcohol, and imported 310,000 gallons, and in that country, to-day, a very large quantity of ethyl alcohol is manufactured from waste sulphite liquors of the pulp mills.[4] . At one of the plants operated for treating sulphite liquors, the process yields about 6 gallons of absolute alcohol for 1,000 gallons of liquor treated, and about 14 gallons for every ton of cellulose. The estimates of the cost of production for a mill in Sweden, producing 340,000 gallons per annum, place the cost at about $9.50 per 100 gallons of alcohol, or 9½ cents per gallon. The cost, including the Government tax per gallon, is about 15½ cents per gallon.[5]

Other sources of alcohol are grain, potatoes, and other products of the soil, and, although these sources are, or could be

[4] *Teknisk Tidskrift*, July 6, 1918 (E. Nordin): "During January to May, 7 factories produced 2.5 millilitres 50 per cent alcohol. Their full capacity, however, is 6 millilitres 95 per cent spirit per year, a figure which is expected to be reached in the immediate future. At the present time 12 plants are under construction, with a yearly capacity of 17.5 millilitres 95 per cent alcohol.

"If all the sufficiently large sulphite plants in Sweden utilized the waste liquor in alcohol plants, a yearly production of 40 millilitres 95 per cent spirit could be obtained."

[5] *The Journal of Industrial and Engineering Chemistry*, July, 1912.

made, practically unlimited and inexhaustible, the cost of utilizing them for the manufacture of alcohol for industrial purposes on a large scale is, at present, too great. In time, however, plants for manufacturing alcohol from potatoes, e.g., may be as common in Canada as they are in Germany to-day.

Summarizing, the sources and production of liquid fuels in Canada are:

1st	Oil fields, imp. gals	8,000,000
2nd	Oil shales	none
3rd	Bituminous coals, benzol, approx. imp. gals	3,000,000
	tar, approx. imp. gals	15,000,000
4th	Wood waste	none
5th	Sulphite liquor	none
6th	Grain, approx. imp. gals	1,000,000
	Total, imp. gals	27,000,000

Possible production, crude and refined oils:

1st	Oil fields, imp. gals	8,000,000
2nd	Oil shales, imp. gals	150,000,00
3rd	Bituminous coals, benzol, approx. imp. gals	17,000,000
	tar, approx. imp. gals	42,000,000
4th	Wood waste, alcohol, imp. gals	34,000,000
5th	Sulphate liquor, alcohol, imp. gals	4,000,000
	Total, imp. gals	255,000,000

In estimating the above possible production of crude and refined oils and other liquid fuels from all sources, the assumption is made that 5,000,000 tons of oil shales, containing an average oil content of 35 imp. gals. to the ton, could be profitably distilled in New Brunswick and Nova Scotia; that the anthracite coal now imported to the extent of 4,000,000 tons be replaced by carbonized bituminous coals, and that wood waste and sulphite liquor to the maximum extent are converted into alcohol. In regard to the oil shale deposits of New Brunswick and elsewhere, any estimates concerning both the average yield per ton of the

entire fields, or the quantity of shales which could be profitably retorted, are only problematical, and are cited merely as an indication of what the possibilities might be. The same applies to the utilization of wood waste and sulphite liquor.

Unless, however, strenuous efforts are made along the lines indicated, to utilize our own sources of oils, Canada will be dependent for liquid fuels on outside sources, in rapidly increasing quantities; and the prosperity of this country, like all others of to-day, is becoming increasingly dependent on mechanical power for all purposes. This is a mechanical age. The immense scale on which mechanical power is employed for all purposes is not understood or appreciated by the great masses.

The term 'conservation,' as applied to natural resources, has been defined as "the wise and intelligent use of them." This implies that any natural product will be used only for that purpose for which it is best suited, or for which no other natural product can be substituted. Thus, petroleum, which is specially suited and is now indispensable for certain purposes, should not be used when another natural product existing in much larger quantities can be substituted without entailing too much discomfort or inconvenience.

For the generation of steam, coal, which is found in great abundance, should be used in place of petroleum, except in very special cases, even though the latter be far more desirable in many ways. In this manner the oils would be conserved for their most valuable use, viz., the generation of power through the medium of the internal combustion engine. To further extend the life of our oil resources, scientific effort must be centred on investigations concerning the utilization of the heavier distillates, resulting from the retorting of crude oils, in such internal combustion motors as are at present entirely dependent on gasoline and the lighter oils.

It has been estinated that if slaves were used to perform the work now being done by mechanical power in the United States alone, over three billion would be necessary. It will therefore readily be seen how man's comfort and happiness are inseparably

linked up with mechanical power, and the ease with which it can be obtained. For although the world, to-day, is disturbed with the grievances of the labourer, skilled artizan, and others, it is a fact that never in the history of mankind have people in general lived in such comfort, surrounded by luxuries of which even the kings of old scarcely dreamed, and it does not require a very powerful imagination to picture what would result if this great source of our progress, comfort, and almost very existence, were suddenly taken from us.

DISCUSSION

MR. J. J. O'NEILL: I think Mr. Haanel made the statement that he had no definite knowledge as to the extent or the general oil content of the shale in New Brunswick excepting for forty tons tested in Scotland, yet he states that he considers there are about 8,000,000 tons available for distillation. On what does he base that figure?

MR. HAANEL: I believe we have a very large tonnage of shale in New Brunswick and Nova Scotia, but the Government has not yet made a detailed survey to determine the approximate tonnage. Such a survey will be undertaken shortly. A certain amount of work, however, has been done on individual properties and the oil content of various samples of shale determined. It was on the test made in Scotland that the figure of 48 gallons to the ton was given. Whether it will increase or average below that I don't know.

From estimates available, concerning the extent of the New Brunswick and Nova Scotia oil shale deposits—which at best can only be considered as very rough estimates—I assumed that 5,000,000 tons of shale per year might represent a tonnage that could be made available for retorting for some time to come. A statement has appeared in print that in Nova Scotia alone there are 500,000,000 tons of oil shales. If I am not mistaken this information was contained in one of the Bulletins of the Canadian Mining Institute.

RATIONAL USE OF COAL FOR POWER AND HEAT*

By John Blizard

(Annual Meeting, Montreal, March, 1919)

Those who require a supply of heat and power for industrial or domestic purposes, may obtain it either by burning raw coal, or the coke, gas or liquid fuels recovered by carbonizing it, or by purchasing electrical energy, steam or compressed air, generated and distributed from a central station burning coal, coke or gas. There are, besides coal, other sources of energy, notably water-power (which generates the bulk of Canada's supply of electrical energy), petroleum and its products, wood, peat and wind power. And coal cannot be said to be applied rationally, unless the use of other sources of energy has been considered and discarded for the particular plant which requires a supply of energy. It is not intended here to compare the relative values of the various sources of energy with coal; nor to attempt to enumerate and criticize all the numerous processes for generating and supplying heat and power obtained by burning coal; but it is intended to discuss some of the principles involved in burning coal for steam raising—largely in the light of experience gained at the fuel testing station at Ottawa—and to outline the possibilities of carbonizing or completely gasifying coal and supplying consumers with gas and coke instead of raw coal.

The coal consumer, who desires to reduce his coal consumption, proceeds by carefully determining the heat losses between the coal and the finished product. He will then find how he may reduce these losses by better control, or by the installation of a new plant. As an example, consider the means of preventing losses in a hand-fired steam boiler plant.

The principal losses in generating steam are those due to:

(1) The removal of combustible matter with the ash and clinker.

*By permission of the Director, Mines Branch, Dept. of Mines, Ottawa.

(2) Unburnt inflammable gases leaving with the flue gas.

(3) The flue gases leaving at a high temperature.

(4) The heat transmitted from the boiler to the surrounding air.

The loss due to the removal of combustible matter with the refuse may be reduced by installing grate bars with air spaces best suited to the coal. The results of a series of tests, with Western coals, carried out at Ottawa, illustrate this. Thus with one coal the reduction of the air spaces increased the grate efficiency from 84 to 95 per cent, and the boiler efficiency from 57 to 62 per cent; but with another coal the reduction of the air spaces decreased the grate efficiency by 4 per cent and the boiler efficiency by 2 per cent. It sometimes happened that an improvement in the grate efficiency, due to a reduction of the air spaces, did not improve the overall boiler efficiency. Thus for the same boiler and a different coal, the grate efficiency when using large air spaces in the bars was 88.6 per cent which increased to 93 per cent when the air spaces were decreased; but this change decreased the corresponding overall efficiency from 58.6 to 53.4 per cent. Further analysis showed that generally throughout the trials the loss due to the dilution of the products of combustion with excess air was greater when the bars with small air spaces were used. For the particular trials referred to, the flue gas loss, due to the increased air dilution, increased from 19 to 29 per cent, which accounted for the decreased overall efficiency with the increased grate efficiency.

The loss due to carbon monoxide, hydrogen, methane and other inflammable gases leaving the furnace may be reduced by increasing the supply of air over the fuel bed to burn them; but if this secondary supply of air be too great, it will so reduce the temperature of the gases in the furnace, and therefore the rate of heat transmission, that the loss due to the increased amount of heat that the larger quantity of gases carry off in leaving the boiler, will more than offset the gain due to the improved combustion.

It is therefore essential not to reduce the losses due to unburnt gases at the expense of too great an increased heat loss due to

the admission of too much secondary air. The results of two boiler trials at Ottawa with the same coal illustrate this. During the first trial the air used to burn the coal was 1½ times the theoretical quantity required, the resulting flue gas loss was 14 per cent, and the loss due to unburnt carbon monoxide 3 per cent, which meant probably that the total loss due to all the unburnt gases was about 6 per cent. In the second trial the air used was 1⅓ of that theoretically required, the flue gas loss increased to 20 per cent and the loss due to unburnt carbon monoxide fell to 1 per cent. The net effect of increasing the air ratio was to reduce the overall boiler efficiency by a little less than 1 per cent. These figures show, therefore, that with this particular coal and boiler it is not economical to attempt to burn the whole of the carbon monoxide.

In order to completely burn the gases without unduly increasing the excess air supply it is necessary to provide a furnace so designed that the secondary air supply may be thoroughly mixed with the gases near the fuel bed and maintained at a high temperature sufficiently long to allow them to burn. A separate brick-enclosed furnace is sometimes used for the purpose of maintaining the gases at a sufficiently high temperature, but this is not always an advantage, since, when used, the cost of upkeep and radiation losses to the surrounding air increase, and the enclosing brick-work prevents the boiler from absorbing radiant heat from the flames and incandescent fuel. Also the freshly fired fuel absorbs radiant heat so rapidly from the hot brickwork that its volatile matter passes off too rapidly for the secondary air to burn it.

A good example of the effect of a change in the furnace on the combustion of the gases is given by comparing the following results obtained when firing peat for steam raising, first, in a water tube boiler, and secondly in a locomotive boiler. The furnace of the water tube boiler had brick walls and was proportionately larger than the locomotive boiler furnace, the side and roof of which consisted of water cooled metal. With the water tube boiler the loss due to unburnt carbon monoxide did not exceed 5½ per cent; but in the locomotive boiler it reached 16

per cent. From these figures it follows that it is difficult to burn the gases completely when firing peat, and that the loss may be reduced very materially by using a larger furnace with brick instead of water cooled metal sides.

The actual transference of the heat to the metal boundary of the boiler takes place by radiation from the flame and incandescent fuel and by convection currents whereby the hot gases from the furnace displace the cooler film of gas which adheres to the metal heating surface of the boiler. The heat radiated varies with different coals, but for the same coal it increases more and more rapidly with an increase in temperature of the fuel bed and flame. This temperature increases when the ratio of air to fuel decreases or when the rate of combustion increases. The heat rays are absorbed so rapidly by the surface of the boiler exposed to it, that the rate of heat transmission per square foot of heating surface exposed to radiation may be over ten times the average rate of heat transmission for the boiler.

The rate of heat transference by convection increases with the temperature difference between the gas and metal plate and with the velocity of the gases passing through the boiler. Tests at Ottawa showed that when the rate of steaming increased by about 50 per cent, the rate of heat transference due to the higher temperatures and velocities did not increase as rapidly as the rate of combustion and therefore the overall efficiency decreased. But this decrease was not very great, as the following figures show:

(1) For a low grade bituminous lump coal an increased rate of steaming of 57 per cent reduced the efficiency of the boiler from 57 to 55 per cent, the flue gas temperature increased from 580° F. to 840° F. and the excess air remained about constant at 50 per cent.

(2) A higher grade bituminous slack coal generated 2,000 pounds of steam per hour with an efficiency of 65 per cent which fell only to 63 per cent when it generated 3,000 pounds of steam per hour. The flue gas temperature increased from 610° to 740°F.

(3) An anthracite coal showed a loss in efficiency of only 2 per cent when fired at a rate 40 per cent greater, and the flue gas temperature increased from 550°F. to 680°F.

These figures show that two boilers steaming at 1½ times their normal rate may take the place of three steaming normally, with very little loss in thermal efficiency. Further, with the higher rate of steaming the gases leave the boiler at a higher temperature, so that there is a good opportunity to instal an economizer to use these gases to heat the feed water and so considerably increase the overall efficiency.

An alternative scheme, whereby the heating surface may be caused to take up heat more rapidly from the gas, is to put in additional baffles. This will lengthen the path of the gas from the furnace to the flue, and so make it necessary, for the same rate of steaming, to drive the gases through at a greater velocity, since the time taken by the gases to pass through will remain practically the same as before. To obtain this increased velocity it may be necessary to enlarge the chimney or to instal a fan. It is important to remember that with natural draft any increase in the mean temperature of the gases in the chimney over 300° F. has very little effect on the rate of combustion, so that frequently it may be possible, where natural draft is relied upon, to reduce the temperature of the gases leaving the boiler by imposing baffles without expending capital to enlarge the chimney to maintain the desired rate of steaming.

The above changes are only a few which the consumer has to investigate by careful analysis of the results obtained in his boiler plant. He should consider also the possibility of using mechanical stokers or powdered fuel, of purchasing other grades of fuel, of increasing or decreasing the ratio of the boiler heating surface to grate area, and many other factors. No change should be made without carefully analysing the probable results and the net possible return from the new investment. The actual best choice of coal and equipment will depend upon so many variables that the best combination for one plant may be the

worst for another. Even the calorific value of the coal is by no means a reliable index to its steaming value. The results of the Ottawa trials showed efficiencies at the same steaming rates on the same boiler, with different coals, to vary from 50 to 65 per cent. And a lump coal with a calorific value of 9,700 B.T.U. per pound generated 5 per cent less steam per pound than a run of mine coal with a calorific value of 9,000 B.T.U. per pound.

The economical generation of power from steam requires as much or more thought than the generation of the steam itself. Even when the choice between the reciprocating engine and the turbine has been made there yet remains the type of turbine or reciprocating engine to be considered. An expensive steam turbine will give, ordinarily, a much better thermal efficiency than a cheaper one. But to get a good return from the outlay a large supply of cooling water must be available and elaborate condensing plant and air pumps must be installed.

It is also frequently possible to dispense with condensers and to use the engine exhaust steam for heating. Where a low temperature load exists this must result in a considerable saving, since an engine using 20 pounds of steam per horse-power-hour actually converts only about one-tenth of the heat of the steam into work, leaving the bulk of the remainder available for heating.

Where exhaust steam passes to the atmosphere and there is no heating process which could use it, it may be possible to generate power with it in a low pressure or mixed pressure steam turbine. With winding and other steam engines, which work intermittently, the steam may be stored in an accumulator, from which it may be taken as required.

It is often more economical for various manufacturers and power users to burn gas made from either the partial combustion or distillation of coal, than to burn raw coal. Gas is a particularly valuable fuel because it can furnish heat with the temperature and intensity desired at any time or place, conditions which the combustion of coal on a grate does not meet with the same facility. It requires very little attention, is easily adjusted to suit

the quantity of heat desired and may be turned on or off as required.

By taking advantage of the phenomenon of surface combustion, it is possible to accelerate the combustion of gas with a quantity of air only slightly in excess of that theoretically required, so that the gas burns in a thin film in contact with a porous surface. The application of this principle enables very high temperatures to be obtained, and therefore a large proportion of the heat to be transferred by radiation. And since there is practically no excess air, the loss due to waste gases is very much below that obtained in ordinary practice. It can be adapted to a large variety of furnaces, and tests have shown efficiencies of over 90 per cent when burning gas for steam raising in a surface combustion boiler.

When gas is used to generate power in a gas engine, thermal efficiencies as high as 30 per cent based on the brake horse-power are common even with comparatively small engines. This efficiency is higher than that for the largest steam turbines, in which a maximum of about 25 per cent is possible with the steam temperatures and pressures used to-day. But it is not usual to build gas engines in sizes beyond 5,000 h.p., which is considered very large, and gas engines are so costly that they can seldom compete with the steam turbine for use in large central power plants.

From the above it is seen that gas must occupy an important position for supplying heat for special purposes and for supplying power in comparatively small quantities; but the advance in its use as a source of heat will be governed somewhat by the supply of oil and by the development of the application of powdered fuel both of which have many similar advantages. As a source of power it will also have to compete with oil which may be burnt in a high compression slow combustion oil engine with a better thermal efficiency than gas in a gas engine.

The gases obtained from coal are: producer gas, coke oven gas, retort gas and water gas, which is generally made from coke. The calorific value of producer gas varies from about 100 to

180 B.T.U. per cubic foot, coke oven and retort gas from 500 to 650 B.T.U. per cubic foot and water gas has a calorific value of about 300 B.T.U. per cubic foot.

The gas obtained by carbonizing coal represents a much smaller fraction of the original energy in the coal than does producer gas, since in carbonization plants the greater portion of the original energy of the coal remains in the coke. The actual relative value of the coke and gas depends upon the system of carbonization used. The manufacturer of town gas aims to get as large a yield of gas of the legal calorific value as possible. He heats the coal in retorts by burning producer gas made from the coke, and often increases the yield by passing superheated steam through the retort, which helps to sweep out the volatile matter and combines with the hot coke to form water gas. Further, he is pressing for legislation to permit him to deliver gas, of a lower heating value than that now permitted, by diluting the coal gas with water gas made from coke in external water gas producers. The reasons for his methods are obvious since he sells heat energy in the form of gas at the rate of about 5,200 B.T.U. for one cent, whereas he sells it in the coke at the rate of about 26,000 B.T.U. for one cent. The coke oven operator on the other hand aims to produce the maximum quantity of a good metallurgical coke. His plant is, therefore, situated as near as possible to his customers and where he may easily obtain a supply of good coking coal at a low price, usually far less than that paid by gas works companies. If he uses a by-product recovery regenerative plant he burns gas to heat the oven and the quantity of gas per ton of coal coked which remains for sale is less than one half of that produced, and he sells it for only about one-tenth the price paid for the same volume of town gas, unless he is near enough to a city where he may obtain the higher price. He, therefore, regards the gas as a by-product. The actual relative revenue to be obtained varies greatly with the fluctuation of the market for by-products and the demand for the coke and gas. The following figures calculated from the United States census of the returns from by-product coking for 1917 are interesting. Of the total returns, the revenue from the sale of coke represented

68 per cent, gas 6 per cent, tar 3 per cent, ammonia 9 per cent and benzol 14 per cent. The possibility of recovering from carbonizing plants many by-products useful in mining and agriculture and for the manufacture of explosives, dye-stuffs, photographic chemicals, perfumes and liquid fuels, lead many to prophesy that the time is not very far off when no coal will be burned in the raw state.

There are many suggestions for further developing this industry. One is to coke coal and to convert the coke into producer gas in by-product recovery producers, thereby recovering from the producer gas much of that portion of the nitrogen which remains in the coke. The richer coke oven gas would be sold to consumers situated far from the plant, and the leaner producer gas to those near the plant. But these gas plants could be exploited only in the midst of densely populated and industrial districts, and are, therefore, unlikely to become common in a sparsely populated country like Canada which has to rely largely on railway transportation and electrical conductors for its supply of energy. This, however, will not prevent the development of the coking industry for the supply of coke to take the place of coal. For domestic purposes, householders prefer anthracite to coke only because it is less bulky, and coke is now burned in hand fired boilers for steam raising in industrial plants. It may in time be possible to produce a coke which by suitable modification of furnaces and mechanical stokers will be preferred to bituminous coal. This substitution would permanently banish the smoke nuisance.

All coals do not coke, but many non-coking coals may be gasified in a producer. With this process less tar is recovered and no benzol scrubbed from the gas, but it is possible by increasing the steam supply to the producer to recover about twice the quantity of nitrogen (in the form of ammonium sulphate) from the coal as is obtained when coal is carbonized in coke ovens or gas retorts. The cost of distributing producer gas is greater than with coke oven gas because of its lower calorific value, but in England large quantities are distributed and sold at extremely

low rates. It might also be used for electric power generation, in which form the energy might be economically distributed to greater distances.

The fuel testing division of the Mines Branch is now conducting experiments with a view to obtaining information for the establishment of a carbonization and briquetting industry in Saskatchewan, to convert low grade lignites into a good fuel. These lignites contain about 35 per cent of water and have a calorific value of about 7,000 B.T.U. per pound. The experiments show that when one ton of dry lignite is carbonized at a temperature of about 600°C. it yields 1,300 pounds solid residue with a calorific value of about 12,300 B.T.U. per pound and 5,500 cubic feet of gas, with a net calorific value of about 400 B.T.U. per cubic foot. But the residue is unsuitable for use on a grate, for which purpose it must be briquetted. The commercial success of the project is rendered more difficult because there is no likelihood of recovering as much tar or ammonia from these lignites as is done in plants using bituminous coals.

THE FORMATION OF COAL

By J. D. Kendall

Since the days of Logan, De la Beche, and Dawson, there has been a generally entertained opinion in Great Britain and North America that coal seams are the remains of forests which grew *in situ*. That opinion is mainly based on the two following facts: (1) That stigmaria are frequently found in the seat-earth or fireclay underlying some seams of coal; and (2) That erect stems of sigillaria and lepidodendron are found occasionally standing above and apparently out of the coal, and elsewhere—sometimes with roots attached—in the measures separating the different seams of coal.

I have never been satisfied that this explanation is agreeable to the facts, and will endeavour in the course of this communication to show why I lean to the opinion that coal has been produced from woody matter that was drifted into position by water and afterwards altered by pressure, heat and chemical change into its present substance.

The observations to be made in this paper will be illustrated by reference to British coalfields, for the reason that they have been more extensively worked than other fields of like extent, and therefore that we may perhaps be able to see more clearly the course of their evolution. Some of the principal British coalfields are shown in Fig. 1.

Rocks in Which Coal Seams Occur

It is very common to find coal seams underlain by fireclay and overlain by shale. But there are many seams in which the roof is sandstone and the sole shale. In some cases the sole is sandstone. In the South Tyne district at Blenkinsop's and other collieries the 'Little Limestone' coal has a roof of limestone and a sole of sandstone. In the Clyde Basin some of the seams have both a roof and sole of sandstone and some a sandstone roof and fireclay floor. In other cases the roof is limestone.

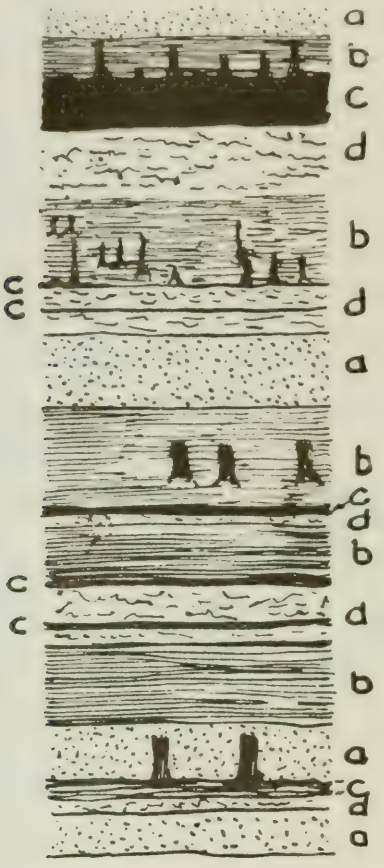
It is considered by those who lean to the opinion that the coal-forming plants grew where we now find coal seams, that the underlying fireclay was the soil in which they grew, and it has been suggested by Sterry Hunt that the potash in these seat-

Fig 1.

earths is low because that substance had been largely taken up by the growing plants. But it seems to me more probable that the reduced quantity of potash, lime and magnesia in fireclay has been brought about by the action of carbonic acid produced in the overlying vegetable matter during the chemical changes which took place in its transformation into coal. Where the sole is either shale or sandstone, Hunt's suggestion cannot, of course, be put forward.

THE OCCURRENCE OF ROOTS AND ERECT TREE TRUNKS IN COAL MEASURES

One of the most interesting sections in this connection that has been unearthed is that given by R. Brown[1] of the lower coal measures of the Sydney coalfield, Cape Breton, and which is here reproduced in Fig. 2.



a. Sandstone
b. Shale
c Coal
d Fireclay

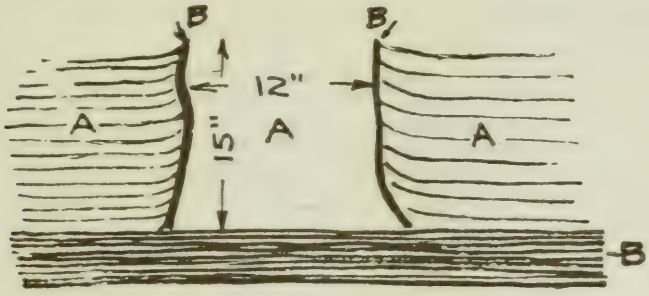
Fig 2

There are six beds of coal, the uppermost being six feet thick; the others are much thinner, the smallest being only

[1] Quart. Journ. Geol. Soc. of London, vol. VI., p. 115.

about half an inch thick. Each seam rests on an underclay containing roots. There are four principal horizons in which the stems or trunks occur. In the uppermost they are embedded in the shale forming the roof of the thick coal. The roots belonging to these stems seem, at first sight, to be included in the seam and to have been converted into coal. In the second horizon the stems have only a small part of their roots, and five of them have no connection with any coal seam. The trees in the third tier are in shale, are unconnected with the underlying thin coal, and most of their roots have been broken off. In the lowest stage the stems are buried in sandstone, their lower ends resting on shale. They have no roots that can be traced.

Stems buried in this way often consist merely of a cylindrical tube of coal in place of the bark, the woody matter originally within having been removed and the space thereby left afterwards filled with mud or other matter, as shown in Fig. 3, which is a sketch of a stem seen by the writer in Lamplugh colliery, Cumberland coalfield.

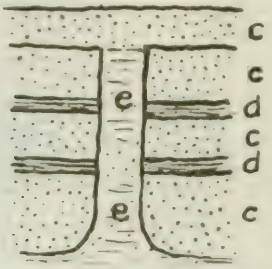


A. Black Scale
B. Coal

Fig 3.

Such trees must have become hollow after partial entombment. The manner in which the upper surface of the seam is continued uninterruptedly under the stem shows, I think, clearly that the layer of woody matter afterwards converted into coal was formed before the stem settled on it, and that therefore there was no root to the stem, so that the root cannot

be supposed to have been converted into coal within the seam. For the same reason the stem could not have passed through the seam, its root being embedded in the underclay. The material within and without these stems sometimes does not correspond, as shown by Fig. 4, after De la Beche[2].



c—Sandstone
d—Shale
e—Shale and Sandstone

Fig. 4

Some trees described by Dawson[3] as occurring in the coal measures of the South Joggins, Nova Scotia, contained reptilian bones which had evidently been introduced during the burial of the trees; Dawson thus describes the occurrence of the bones in one of these trees:—

"Like all other trees in which reptilian bones have been found it sprang immediately from the surface of the 6-inch coal in group XV. of my section (uppermost seam in Fig. 2). Its diameter at the base was 2 feet and height 6 feet. The bark is well preserved in the state of bituminous coal. At the bottom is the usual layer of mineral charcoal consisting of the fallen wood and bark of the tree itself. Above this, about 2 feet of its height are filled with a confused mass of vegetable fragments consisting of *Cordaites*, *Lepidodendron*, *Ulodendron*, *Lepidostrobus*, *Calamites*, *Trigonocarpum*, stripes and fronds of ferns, and mineral charcoal, the whole embedded in a sandy paste blackened by coaly matter. In and at the top of this mass occur the animal remains. The remainder of the trunk is occupied by grey and buff sandstone, containing a few fragments of plants, but no remains of animals. . . . Portions of six skeletons were

[2] Geological Observer, p. 504.
[3] Quart. Journ. Geol. Soc. of London, vol. XVIII, p. 5.

obtained from this trunk. The most important of these is a large and complete skeleton of *Dendrerpeton Acadianum*."

From the fragmentary character of the bones and plants included in this trunk we may, I think, fairly infer that they were drifted in after the trunk had been partially buried.

I submit there is nothing in the manner in which any of these trunks occur that cannot be better explained on the assumption they were drifted into position by water, than by supposing them to have grown on the spot. In the latter case there ought to have been complete roots on every erect stem unless they had been converted into coal, whereas, if drifted with some of the soil in which they grew adhering to the incomplete roots they would assume a more or less vertical position when drifted into a body of still water. Further, trunks broken off at the ground level and thicker at one end than the other would, after being water logged, sink in a more or less vertical position—the heavier end downwards. I have seen scores of semi-submerged trees, after the spring floods, in the Upper Arrow lake, where the Columbia river enters. Their upper ends were standing out above the surface of the lake, and had all the appearance of trees which had grown on the spot and been partly buried by flood water. Both lake and river were in flood, but these trees were not there before the flood.

There is other evidence, in comparatively recent vegetable deposits of drift origin, that trunks frequently occur in such deposits in a vertical position. In a paper on the Interglacial deposits of West Cumberland and North Lancashire[4] I described a number of drifted vegetable deposits which, in several of their features, closely resemble coal seams. Most of the deposits occur on the sea-shore and usually pass by the name of "submerged forest," but they are not forests, nor the site of forests, simply accumulations under water of drifted vegetable matter.

[4] Quart. Journ. Geol. Soc. of London, Feb., 1881.

A cross section of one of these deposits, which occurs on the sea-shore at St. Bees, is reproduced in Fig. 5.

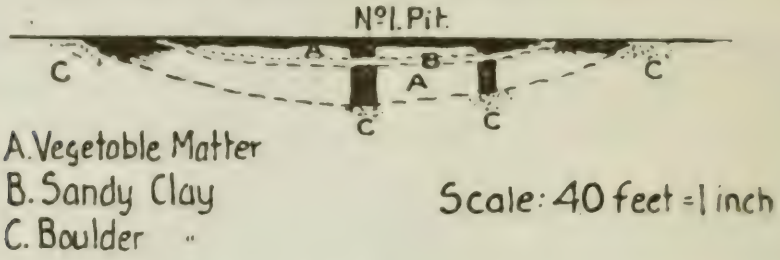


Fig 5

In this deposit I sank several shafts and boreholes. The particulars of one of them were as under:—

Thickness

A 1′0″ Vegetable matter (brown) and grey sand in layers of different thicknesses. The vegetable matter consists of seeds of various sizes, leaves and stems of rush-like plants, hazelnuts, leaves and wood of the oak, alder and hazel. The rush-like stems are numerous and vary in length from one to three inches. A vertebral column about the size of that of a rat was also found in this bed.

B 2′0″ Grey sandy clay containing a few rush-like leaves and the elytra of beetles.

C 6″ Hazel wood, nuts and leaves, also leaves of the oak, beech, and alder.

D 5′0″ Similar to A, but containing more leaves and hazelnuts. The deposit resting on lower boulder clay.

The vegetable matter is laminated as if by pressure, probably from the upper boulder clay, since denuded. In parts of this and other similar deposits tree trunks are found lying on their sides, and there are numerous root-stocks, some of which have belonged to trees 18 inches in diameter. In some cases the roots were attached to short trunks which stood in the deposit in the position of growth.

We see in these deposits similar underclays to those which frequently accompany coal seams and the same kind of intercalated clay and sandy bands.

COAL BASINS

Several of the British coalfields are in well-defined basins, such as those of South Wales, the Forest of Dean, Burnley, Ayrshire, and the Clyde coalfield. In other fields there was probably a similar basin-like form originally which has been to some extent destroyed by faulting. Besides, parts of them are so concealed by newer formations that it is not possible to speak more definitely. Edward Hull, in his "Coalfields of Great Britain,"[5] says: "It must not be supposed that this basin-shaped arrangement of the upper Carboniferous strata was the original form in which the coalfields were deposited, like so many lakes filled with sediment and surrounded by hilly banks and barriers. Such an idea would be altogether erroneous."

Hull was an advocate of growth *in situ* and supposed that the coal measures in Britain originally covered: "two large tracts, one to the north, the other to the south of a band of country stretching from North Wales, through Shropshire and Worcestershire to the Eastern Counties. The Highlands of Scotland formed the limit to the northward. Through these great sheets of Carboniferous rocks the Cumberland mountains and a little of the southern uplands of Scotland protruded. . . . With these exceptions we have the most conclusive evidence that the coal measures were continuous on the large tracts occupying the center of Scotland, the north of England and the south of England (see Fig. 6 after Hull)."

The extent of the coalfields, originally, he supposes was about 42,000 square miles, whereas their present extent is only about 3,000 square miles.

On comparing this drawing with Fig. 1, the immense destruction which Hull supposes the British coal measures have undergone will be realized by many with considerable surprise.

[5] 3rd Edition, p. 463.

Had the destruction been so great, it would simply afford a further powerful illustration to the many already known of the wasteful methods that obtain in some sections of nature's laboratory. But the evidence does not support Mr. Hull's conclusion. Coal has been found in Kent, but under London and for 20

Fig 6.

miles to the north, as far as Ware, pre-Carboniferous rocks occur immediately below Mesozoic strata, and there is no evidence that coal measures ever existed at either of these places. It is said by Mr. Hull that at Harwich 44½ feet of "black slaty rock," found, in a borehole, beneath 888 feet of chalk and 61 feet of green-sand, at a depth of from 1,026½ to 1,700 feet, are of lower Carboniferous age, on the following slender evidence:—"Its cleaved character, the absence of lime and the trace of one fossil shell—apparently a large *posidonia*."

Beyond the coalfields of Bristol, the Forest of Dean and

South Wales, two boreholes[6]—one at Barford in Oxfordshire, the other at Northampton—and the small Bovey deposit there is nothing west of London to justify the extensive area assumed by Mr. Hull as former Carboniferous forest land. There is the same lack of evidence with reference to his northern area. Outside the actual coalfields there is nothing except the Grits, Yoredales and Carboniferous Limestone of the Pennine Range that could suggest, even in the least degree, the area Mr. Hull assumes, but it cannot be said, with any approach to certainty that wherever the lower Carboniferous rocks occur, the upper measures must at one time have existed. This remark will be clearer when the perturbations of the Carboniferous strata are considered in the sequel. In reference to the formation of the coal basins Hull says:—"At the close of the carboniferous period terrestrial movements took place over the whole of the British Islands and the neighbouring parts of the continent of Europe. These movements seem to have produced their most powerful effects upon the strata in the south and north of England, and are less discernible in the central part. The forces took the form of lateral pressure, acting in approximately north and south directions and producing flexures in the Carboniferous strata at right-angles thereto; in other words, along axes ranging nearly east and west . . . One of the great arches which itself included several minor folds was formed over the tract between the Yorkshire and Lancashire coalfields on the south and the Durham coalfield on the north. The denudation which took place over this tract laid bare the Millstone Grit and Yoredales and determined the boundaries of the coalfields just named. . . . Another axis or system of flexures, originated along the southern margin of the Carboniferous limestone region Derbyshire, extending westward along the valley of the River Dane, north of Congleton Edge, beneath the Triassic plain of Cheshire, emerging on the western side at the southern end of the Flint coalfield. This Carboniferous axis forms, in my opinion, the southern boundary of the Lancashire and Cheshire coal-basin. Other east and west flexures were also originated at

[6] "On the Possibility of Finding Workable Coal Seams Under the London Area", by J. W. Judd, *Nature*, vol. XXV., p. 311.

this period, the most important being those of the southwest of England, shown by the longer axis of the South Wales coalfield and the uprising of the Carboniferous limestone of the Mendips. . . . All these leading flexures, ranging east and west approximately, accompanied by the denudation of a vast amount of upper Carboniferous material took place before the Permian strata were deposited. . . . At the close of the Permian period, a new series of terrestrial movements took place, but *now* along lines ranging approximately north and south and nearly at right-angles to those which preceded them. These disturbances, accompanied by denudation acting along the arches or anticlinal axes, resulted in the disseverance of the coalfields of Lancashire and Cheshire on the one side, from those of Yorkshire, Derbyshire and Notts on the other. . . . During the same period of disturbance the western limits of the Flintshire and Denbighshire coalfields were determined, also the north and south axes along which the Durham coalfield is inferred to rise and crop out beneath the sea which is supposed to form the eastern limits of the Derbyshire coal-basin. In the same period may also be inferred the disseverance of the South Wales from the Forest of Dean coalfield and the sharp uprise along the east of the Somersetshire coal-basin. . . . I have thus shown that the Carboniferous rocks owe their basin-shaped structure to the intersection, nearly at right-angles, of the two systems of flexures, viz., (1) The earlier being pre-Permian, ranging along approximately east and west lines. (2) The latter being pre-Triassic, ranging along approximately north and south lines."

Mr. Hull had large experience of the British coalfields whilst on the Geological Survey of Great Britain, but I think it will be easy to show that his inferences with regard to the formation of coal-basins are not justified by the facts. In the first place, if it could be admitted that the latest movements which gave rise to the east and west flexures were pre-Permian, and the latest movements that produced the north and south flexures, pre-Triassic, there is nothing to show that these compressive movements took place all at once, or that their earliest movements did not occur in middle coal measure times. Further, a paper

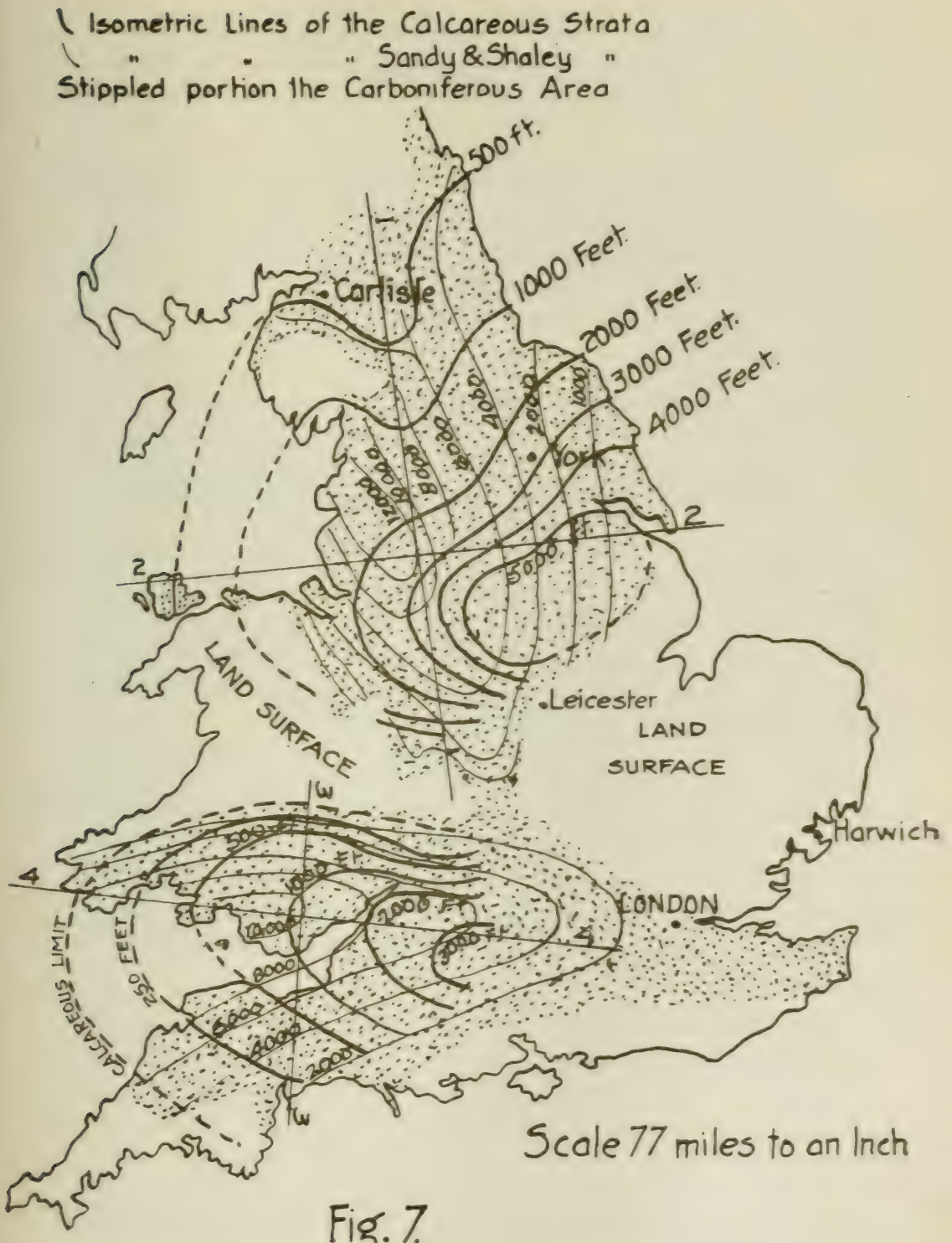

Isometric Lines of the Calcareous Strata
" " " Sandy & Shaley "
Stippled portion the Carboniferous Area
500 ft.
1000 Feet.
2000 Feet.
3000 Feet.
4000 Feet.
Carlisle
Leicester
LAND SURFACE
LAND SURFACE
Harwich
LONDON
CALCAREOUS LIMIT
250 FEET
Scale 77 miles to an Inch

Fig. 7.

read by Mr. Hull[7] before the Geological Society of London shows that the whole Carboniferous system was deposited in basins. That paper is illustrated by a drawing, of which Fig. 7 is a reproduction.

Although said to have been prepared from data procured by the Geological Survey, the drawing can only be used in a general way, as will be seen later when more detailed information is produced. From the isometric lines on that drawing I have prepared four vertical sections which are given in Figs. 8, 9, 10 and 11.

Fig. 8—Over a nearly N. and S. line between 1 and 1.
" 9— " " E. and W. line between 2 and 2.
" 10— " " N. and S. line between 3 and 3.
" 11— " " E. and W. line between 4 and 4.

From these sections it will be seen that the whole of the Carboniferous strata were deposited in basins, a fact which does not seem to have been realized by Mr. Hull. Whether the basins were initially of the size shown in these sections cannot be said. They may have been deepened and reduced in extent during late Carboniferous times.

The basins thus shown are not, of course, the coal basins. But when sections are prepared of the lower Carboniferous strata along the more important coalfields, we begin to see how the coal basins were formed. Fig. 12 is a section from Mid-Northumberland into Derbyshire along the west side of the Northumberland and Durham coalfield, and of the Yorkshire and Derbyshire field.

In preparing this and the two following sections, the base of the coal measures was assumed to be a level plane and the thickness[8] of the Grits, Yoredales and Carboniferous limestone set off from that datum. From Fig. 12 we see that the Carboniferous rocks, under the coal measures of Northumberland and

[7] On Iso-diametric lines as a means of representing the distribution of sedimentary clay and sandy strata, etc., Quart. Journ. Geol. Soc. of London, Vol. XVIII., p. 127.

[8] As determined by officers of the Geological Survey.

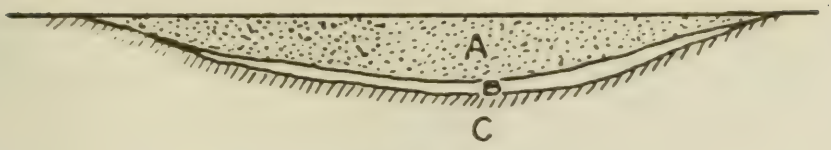


Fig 8.

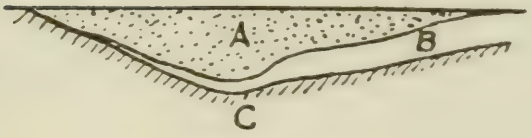


Fig 9.

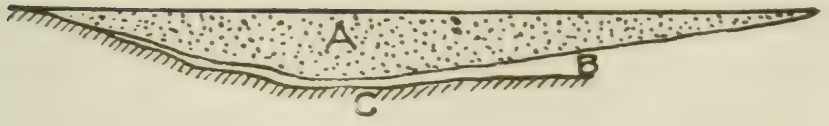


Fig 10.

Fig. 11.

A. Argillaceous & Arenaceous Rocks
B. Calcareous Rock
C. Pre-Carboniferous Rocks
Horizontal Scale 77 Miles to an Inch.
Vertical " 40,000 ft. " "

Durham, were deposited in a basin. So were those under the Yorkshire and Derbyshire coal measures. These basins in the pre-Carboniferous rocks existed before the Carboniferous system

began to be formed and were not due to post-Carboniferous movements, as suggested by Mr. Hull, for the basins occupied by the coal measures.

Fig. 13 is a section along the east side of the Lancashire coalfield and into the North Staffordshire field. It shows that a pre-Carboniferous basin occurs under the Lancashire coalfield and in all probability there is one also under that of North Staffordshire, but the data necessary to complete the basin there are wanting.

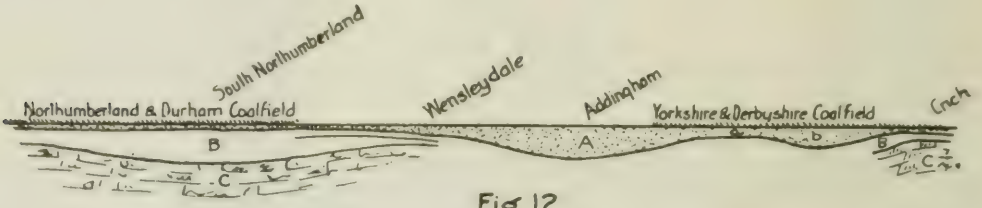


Fig 12

As in Fig. 12 the anticline between the basins is of pre-Carboniferous age.

Fig. 14 represents a section of the South Wales coalfield and part of the Bristol field.

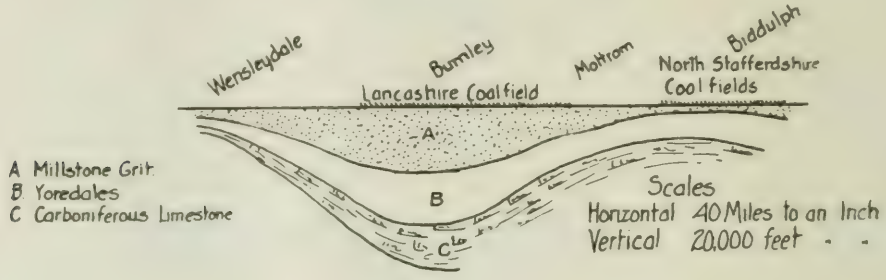


Fig. 13

Here again we see a pre-Carboniferous basin under each coalfield. It is not possible to complete the Bristol basin on the east as the Carboniferous strata there are overlain by later rocks.

It would have been more satisfactory if cross sections could have been produced, but unfortunately the necessary information, for one reason or another, cannot be obtained. It is,

however, favorable to the idea I am seeking to enforce that the Yoredales on the west of the Northumberland coalfield and but a short distance away expand toward the centre of that basin. At West Plainmeller those rocks have a thickness,

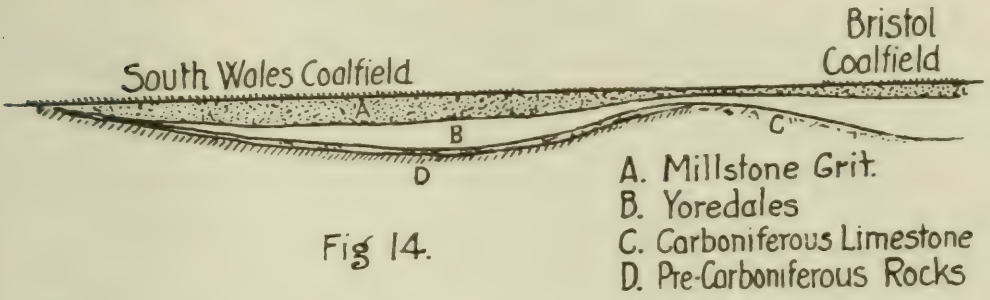


Fig 14.

between the Fell Top limestone and the Little Limestone of 467 feet, but at Coastley, 12 miles east, they are expanded to 556 feet.

In preparing Figs. 12, 13 and 14, it was, as already stated, assumed that the upper surface of the Grits was a level plane merely for the purpose of obtaining a datum from which to plot the different thicknesses of Grits, etc. But facts to be referred to later make it practically certain that when the coal measures began to be deposited the upper surface of the Grits in each of these cases was in the form of a basin, that is to say, the original basins in which the Carboniferous limestone, the Yoredales and the Millstone Grit were formed had not been filled. The actual extent of these basins cannot be determined now, but it certainly was much beyond what it is now, although considerably less than the pre-Carboniferous basins, for, as the lower Carboniferous rocks were deposited in them and the basins gradually filled, their area would become less and less.

Mr. Hull[9] was under the impression that the Carboniferous rocks of the North of England had a south-easterly attenuation, and gave the following figures as to thickness in support thereof:

[9] Coalfields of Great Britain, 3rd Ed., p. 459 and Journ. Geol. Soc. of London, Vol. XXIV, p. 319 (1868).

	Burnley District North Lancashire	*Mottram District East Cheshire*	*North Staffordshire*
	Feet	Feet	Feet
Coal Measures.....	8,460	7,630	6,000
Millstone Grit Series...	5,500	2,500	500
Yoredales.....	4,670	2,000	2,300
	18,630	12,130	8,800

The figures for North Staffordshire given in the above table —taken from p. 460 of the "Coalfields of Great Britain", 3rd Ed.—differ from those on p. 173 of that work. There we find the Millstone Grit stated to be 1,000 feet thick and the Yoredales 3,100 feet.

A reference to Fig. 13 will make it clear that this supposed south-easterly attenuation does not exist. It is merely an accidental result due to the particular places for which the figures were given by Mr. Hull. If instead of Burnley, Mottram and North Staffordshire, we take Wensleydale, Burnley, Biddulph, and lastly the southern part of the North Staffordshire field, we get a set of figures quite different from those given by Mr. Hull. They show first an *expansion* to the southeast, then an attenuation, followed by a second expansion. In his paper on isodiametric lines[10] Mr. Hull says:—"In any natural group or system of strata, consisting on the one hand of sedimentary strata, and on the other of calcareous, it appears that the direction of the greatest vertical development of the one will be that of the smallest vertical development of the other. In a word, where the one becomes thin, the other becomes thick."

This statement is not in agreement with the facts presented in Figs. 8, 9, 10 and 11, which were prepared from Mr. Hull's own data, and it is quite at variance with the facts set forth in

[10] Quart. Journ. Geol. Soc. of London, Vol. XVIII., p. 145.

Figs. 12, 13 and 14, in which the greatest thickness of argillaceous and arenaceous rocks occurs at the same point as the greatest thickness of calcareous rocks, that is at the centre of the basins.

The material deposited in the pre-Carboniferous basins shown in Figs. 12, 13 and 14, expands towards the centre of these basins, and if the coal measures were deposited in basins we ought to find their constituent strata similarly expanding toward the centre. That is what we do find where the information is sufficient to enable us to pursue this line of enquiry. A few examples will perhaps help to a fuller appreciation of this statement. The expansion of the measures in the South Wales coalfield toward the west, between the coal above the Black Pins ironstone and the base of the measures is shown by the following figures:

	Feet
At Abersychan Ironworks the thickness is	350
" Fartag " "	420
" Clydach " "	471
" Blaina " "	538
" Nant-y-glo " "	610
" Rumney " "	696

From Abersychan to Rumney is about 9½ miles, so that the expansion is about 1 in 146 from the eastern end of the field toward the centre. The rate is about the same if any of the intervening points be taken. At Abersychan there is an aggregate of 64 feet of sandstone and 272 feet of shale and coal or 1 to 4.2. At Rumney there is 58 feet of sandstone and 638 feet of shale and coal, or 1 to 11.

In the South Staffordshire coalfield there is the remarkable splitting up of the thick coal, from south to north, that is, toward the centre of the basin. The commencement of the splitting up is shown in Fig. 15.

From Bilston the intervening sandstone and shales expand so rapidly that at Essington Wood, about 5 miles north of Bilston, their aggregate thickness is about 407 feet, and the

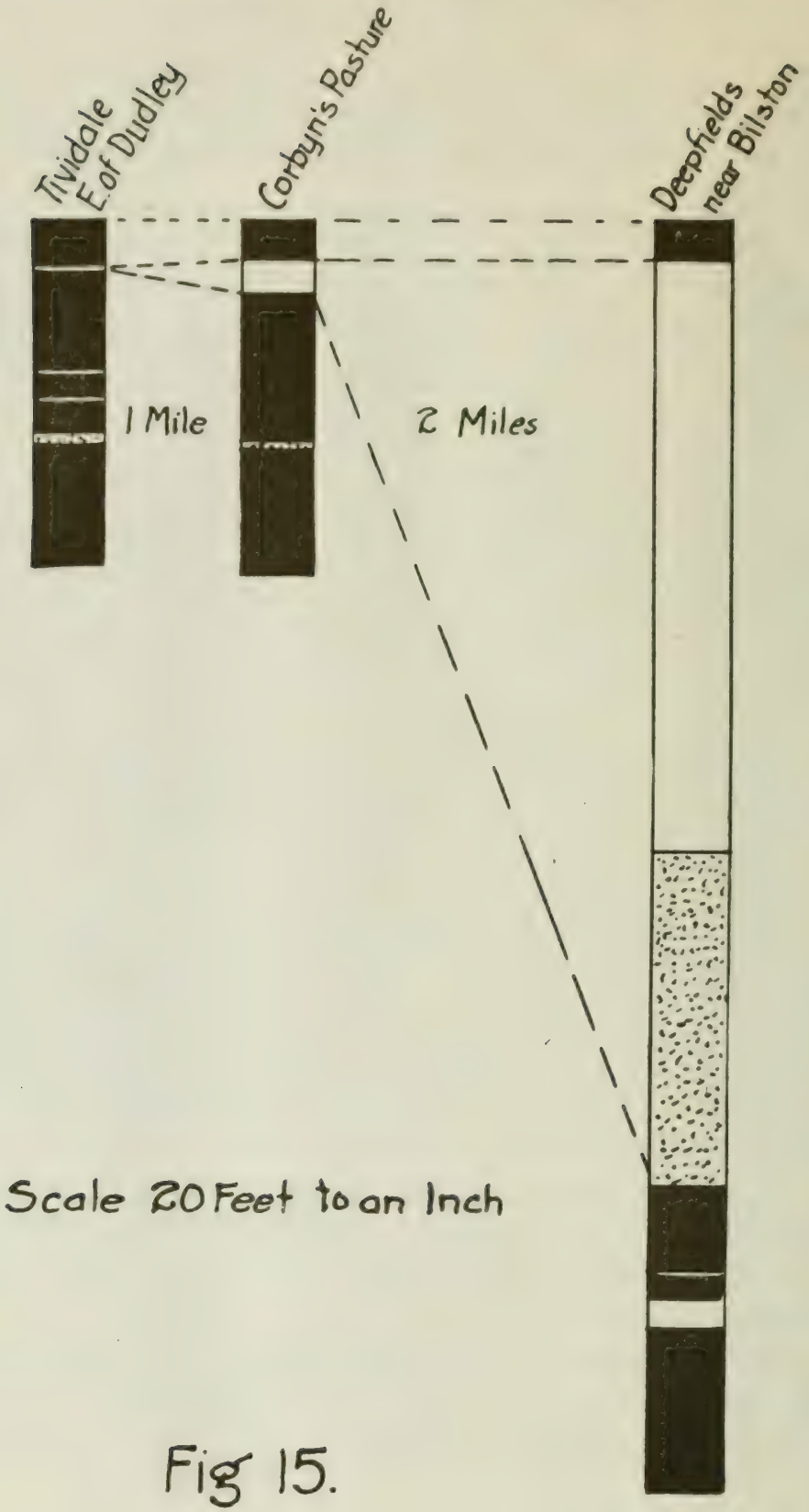

Tividale
E of Dudley
Corbyn's Pasture
Deepfields
near Bilston
1 Mile
2 Miles
Scale 20 Feet to an Inch

Fig 15.

seam which at Tividale, east of Dudley is about 30 feet thick, including six thin partings, is split up into nine seams, of 2 feet and over, having an aggregate thickness of about 43 feet. There is, at the latter point, 37½ feet of sandstone and 369 feet of shale, or 1 to 9.9.

In the Warwickshire coalfield we find a similar expansion northward, as shown by Fig. 16, after H. H. Howell.[11]

In the Yorkshire coalfield[12] the Beeston Bed coal in the Gannister or lower measures, as it occurs at Leeds, is split up in going southwest to Mirfield—a distance of about 7½ miles—so that the top part of the seam there is separated from the bottom part by about 60 feet of strata. At the Woodlesford colliery the Old Hards coal, in the middle measures, is separated from the First Brown Metal coal by about 2 ft. 3 in. of measures, but

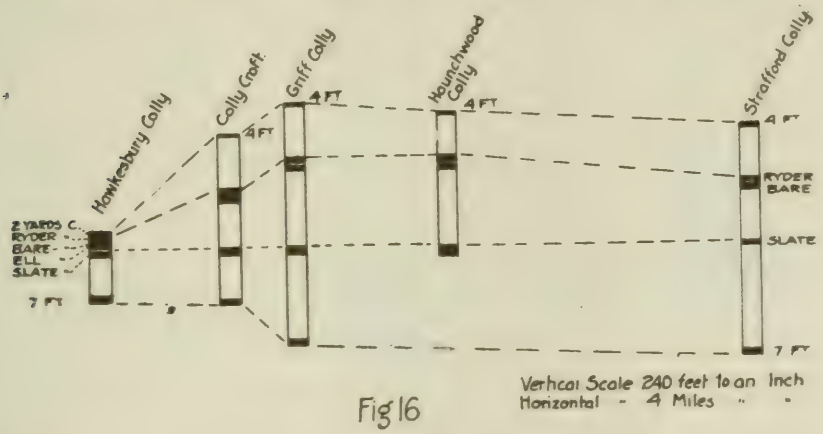


Fig 16

at Rothwell Haigh colliery—only two miles away—they are separated by about 56 feet of strata, an expansion of 1 in 188. The measures between the Silkstone coal and the Barnsley coal at Horbury have a thickness of 1,006 feet. But at Handsworth —20 miles to the south—they have expanded to 1,137 feet. At Pontefract the Aston Common coal is 358 feet above the Barnsley coal. At Handsworth—27 miles to the south—it is 550 feet above. These expansions correspond in direction to

[11] Geol. Sur. Memoir, 1859.

[12] Geol. Sur. Memoir, 1878.

those of the underlying grits, as is seen by reference to that part of Fig. 12 between A and B. This coalfield is shallow in proportion to its length, and therefore the expansions are not so rapid as in basins that are deeper in proportion to their transverse dimensions.

The Lancashire coalfield is in a deep pre-Carboniferous basin and the expansion of the measures is consequently greater than in a comparatively shallow basin like that under the Yorkshire field. C. E. de Rance, of the Geological Survey, in a paper read before the British Association[13] puts the expansion of the middle measures, from south to north, for a distance of 10 miles, at 60 feet per mile, or 1 in 88. Confirmation of this is, to a certain extent, obtained from Hull's "Coalfields of Great Britain," in which, on p. 187, 3rd Ed., the following statement occurs:—"There is a general thickening of the sedimentary material, as sandstones and shales, towards the north-northwest. That is, the *same* coal seams are further apart at St. Helens than at Prescott; and at Wigan than at St. Helens."

In the Cumberland coalfield similar expansions occur. At Clifton colliery the 10/4 coal is 416 feet above the 6/4 coal. At Workington—2½ miles to the west—it is 543 feet above, or an expansion toward the centre of the basin of 1 in 104. At Cleator Moor the same seams (or their equivalents) are 386 feet apart, and at Whitehaven, 3 miles to the west, 484 feet, an expansion of 1 in 158. At Cleator Moor there are 183 feet of sandstone and 302 feet of shale, or 1 to 1.6. At Whitehaven there are 150 feet of sandstone and 384 feet of shale, or 1 to 2.5.

The Main Band at Whitehaven is split up northward as shown in Fig. 17.

It will have been noticed that the ratio of shale to sandstone, in every case, increases toward the centre of the basins, but sometimes we meet with sandstones which do not appear to be explainable on that view. A suggestion of J. A. Phillips[14] may

[13] B. A. Report, 1876.

[14] History of Grits and Sandstones; Quart. Journ. Geol. Soc. of London, Vol. XXXVII, p. 6.

overcome the difficulty. He says:—"A considerable number of sandstones belonging to the Carboniferous period are chiefly composed of quartz crystals, which have evidently crystallized *in situ* since they exhibit the freshness of outline peculiar to

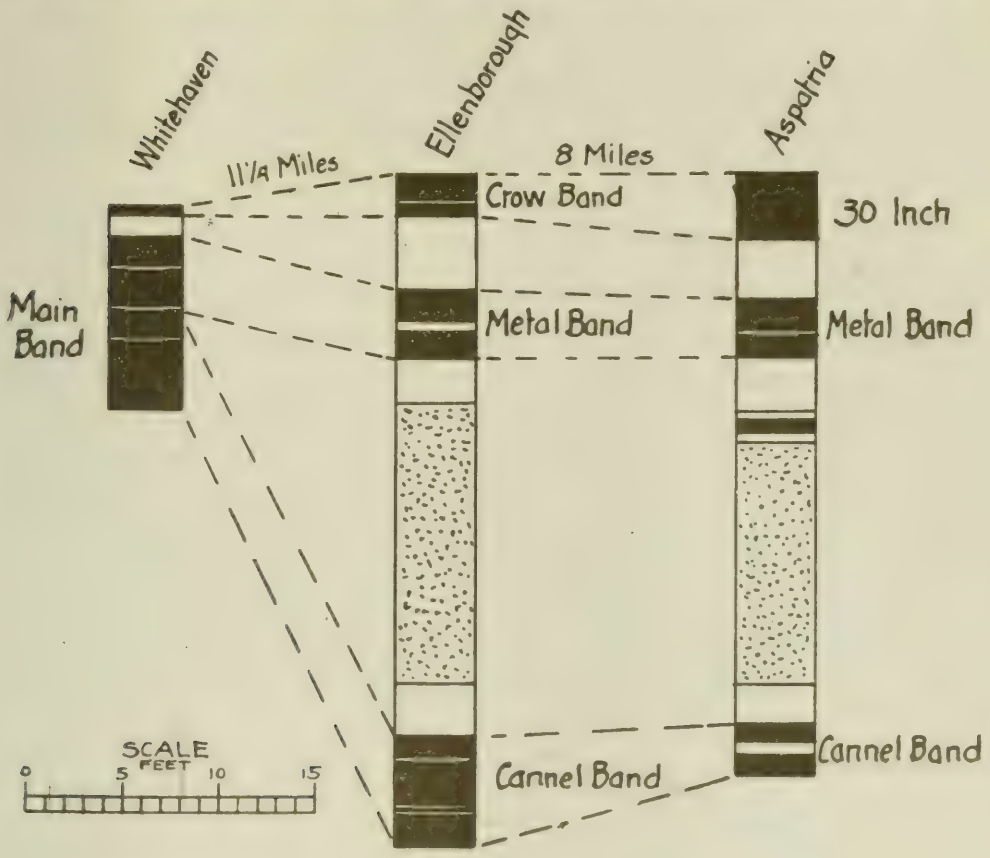


Fig 17.

crystals which have not been subjected to the slightest amount of abrasion."

Further, there is the statement of Daubrée[15] that the diameter of grains capable of floating in slightly agitated water is about 1/250 inch, and he remarks that the smaller grains must of necessity remain angular.

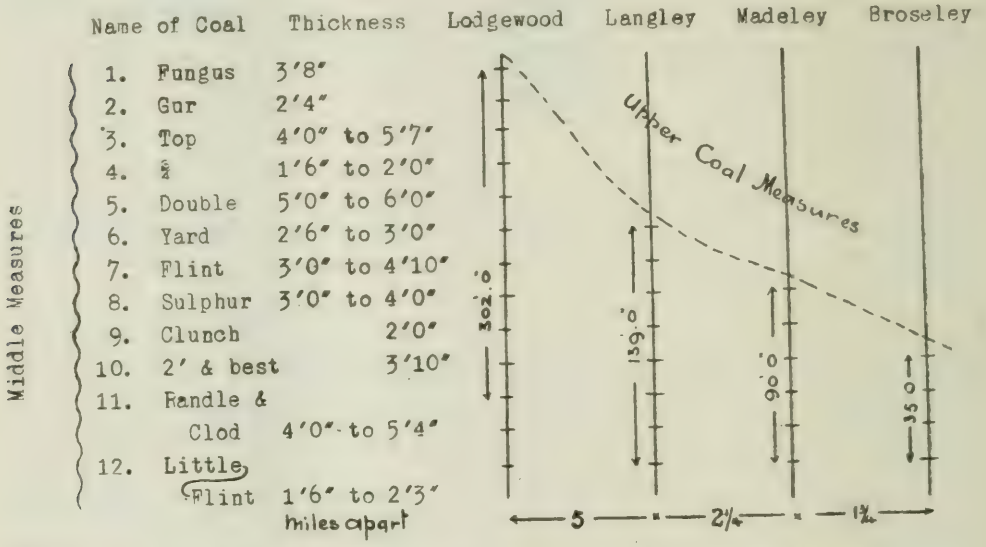
All the expansions, above alluded to, are toward the central or deeper part of their respective fields and indicate as clearly

[15] Geologie Experimentale, p. 256.

as anything can do that the coal measures were deposited in basins. What their original extent was we have no means of fixing, but we know that they have been reduced in size by faulting, horizontal compression and denudation. Some of the compressions are of post-Carboniferous age; others, in all probability, took place during the Carboniferous period, there being in some coalfields the most distinct evidence that very important movements of the earth's crust occurred during Upper Carboniferous times.

CRUST MOVEMENTS DURING THE COAL MEASURE PERIOD

In Coalbrook Dale the upper coal measures, having an ascertained thickness of 573 feet, contain very little coal, the seams being thin and of small extent. These measures are laid unconformably on a denuded surface of the middle measures,[16] which contain 12 principal coal seams having an aggregate thickness of 36 to 45 feet. The thickness of the middle measures, between the upper part of the Chance Pennystone and the Clod coal is about 360 feet, made up of 93 feet of sandstone and 267 feet of shale, or 1 to 2.87. The total thickness of the upper and middle measures is about 933 feet. The following diagram illustrates, in a general way, the unconformity.



[16] This fact was first brought out by Marcus N. T. Scott; Quart. Journ. Geol. Soc. of London, Vol. XVII, p. 457.

At Amie's Field, near Broseley, there are 357 feet of upper measures above the Best coal, in which there is only one seam of coal (about 2 feet thick). There is 147 feet of sandstone, the remainder—210 feet—being shale and a 4 feet bed of limestone; ratio of sandstone to shale 1 to 1.4.

At Madeley, there are 573 feet of measures above the Sulphur coal, 267 feet are sandstone, and 306 feet shale and coal or 1 to 1.1. There are seven seams of coal, one about 2 feet, the others under 9 inches.

At Langley, there are 371 feet of measures above the Yard Seam containing only four beds of coal. One, called the Chance, 9″ thick, the other three are 12″, 9″ and 6″, respectively, and close together, being separated by partings of 6″ and 24″ of shale. There is 140 feet of sandstone and 231 feet of shale, or 1 to 1.6.

Clearly there was a long internal between the deposition of the middle and that of the upper measures. The country must have risen out of the waters at least 360 feet after the deposition of the middle measures, have then been subjected to severe denudation for a time, and subsequently depressed at least 630 feet, prior to or during the formation of the upper measures. Movements of such magnitude would in all probability affect a large area of the adjoining country, and as a consequence we find some unusual occurrences to the west and south. The Shrewsbury coalfield, consisting entirely of upper coal measures, rests on Silurian and Cambrian rocks. Upper coal measures only are likewise found in the Forest of Wyre coalfield, and at the Clee Hills. At the Forest of Wyre and the Brown Clee Hill they rest on Old Red Sandstone, but at the Titterstone Clee Hill, Millstone Grit intervenes. In the southern part of the Forest of Dean, coal measures rest directly on Old Red Sandstone, and at the west end of the South Wales field they lie on Lower Silurian and Cambrian rocks.

It is usually supposed that these areas, in which the coal measures rest on pre-Carboniferous rocks, were dry land during the period represented by the missing formations. But when

we see the amount of denudation that took place during part of the coal measure period, by which nearly the whole of the productive strata at the southern end of the Coalbrook Dale field were swept off it is not improbable that further south, that is, in the Forest of Wyre and the Clee Hills, denudation might dig still deeper and remove from those areas not only the middle and lower coal measures, but the Millstone Grit and perhaps in places the Carboniferous limestone as well, although the occurrence of Millstone Grit, at the Titterstone Clee Hill, directly on Old Red Sandstone is suggestive of dry land there when the Carboniferous limestone was forming. Over part of the Coalbrook Dale field the Carboniferous limestone, the Millstone Grit and the lower coal measures are wanting—the middle measures resting on Silurian.

The submergence which preceded the deposition of the upper coal measures at Coalbrook Dale clearly extended southward beyond the Forest of Wyre and the Clee Hills.

In the Cumberland coalfield we find a similar unconformity of the upper to the middle measures, as pointed out in my papers on the structure of the Cumberland coalfield[17] and the Whitehaven Sandstone series.[18] The middle coal measures, where fully developed, are about 800 feet thick, and contain 24 seams of coal, having an aggregate thickness of about 54 feet, but only seven of them have been worked to any extent. These have a combined thickness of about 31 feet. The greatest thickness of the upper measures known to me is also about 800 feet. This is near Bolton, where eight seams of coal were passed through, but only one of them has been worked, the others being too small. The worked seam is probably the same as the Senhouse High Band, in the Ellenborough colliery.

In the "Whitehaven Sandstone Series" I say: "From a number of sections taken at random, in different parts of the district, the sections ranging from 131 to 450 feet in depth and embracing an aggregate thickness of more than 2,000 feet of

[17] Trans. North of England Inst. of M. and M. E., Vol. XXXII, p. 319 and Vol. XXXIII, p. 143.

[18] Trans. Federated Inst. of M. E., 1895.

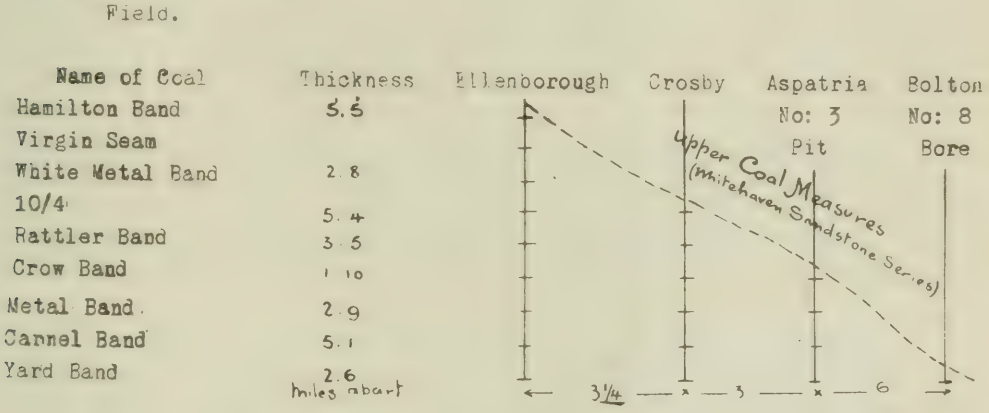
rock, it appears that the proportion of arenaceous and argillaceous rocks in the Whitehaven sandstone series and in a like thickness of middle coal measures, occurring immediately below the purple-grey rocks of the former series is, on the average, as under:

	Sandstone %	Shale %
Whitehaven sandstone series	60	40
Middle coal measures	34	66

The aggregate thickness of coal in the above sections was as follows:

	%	%
Whitehaven sandstone series	7½ ft.	or 0.3%
Middle coal measures	122 ft.	or 6.0%

The unconformity at the northern end of the field may be illustrated in a manner similar to that employed in the case of the Coalbrook Dale field.



The unconformity at the southern end of the field is shown by Fig. 18 taken from my paper on the "Whitehaven Sandstone Series."

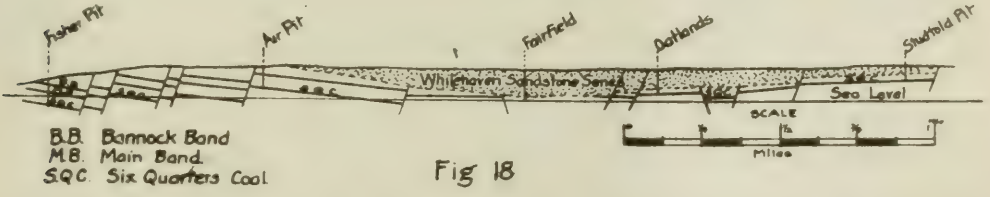


Fig 18

The magnitude of the elevation and subsequent depression necessary to produce the stratigraphical arrangement exhibited

in this section will be more fully appreciated when considered in connection with the following figures.

Altitudes measured from a datum 1,000 feet below high water spring tides.

	6/4 Coal	Base of Whitehaven Sandstone Series	Differences
	Feet	Feet	
At Wellington Pit, Whitehaven	222	891	669
" Oatlands	994	1,074	80
" Studfold	1,373	1,510	137
" Dean Moor	1,441	1,572	132

There are at Wellington Pit 669 feet of middle measures between the 6/4 coal and the base of the upper coal measures —or Whitehaven sandstone series. At Oatlands Pit, 4¼ miles away, there are only 80 feet of rocks between the same two points.

There must have been an elevation in this district at the close of the middle coal measure period of 800 feet or more in some parts of the field and, after a period of denudation, a depression of at least a like amount.

Both the Cumberland field and that of Coalbrook Dale are on the flanks of Silurian areas which doubtless stood out of the waters during Carboniferous times and most probably were included in the uplift which affected the adjoining coalfields. Whether the whole of the intervening area and how much of the areas occupied by the coalfields to the east and south were included in these movements we cannot say, but such large oscillations as occurred in these regions are not likely to have been confined to small areas; and it is practically certain that during the uplift numerous faults of extension would be produced by which the coal areas would be so intersected that after denudation they would be seriously reduced in extent. Some of the faults by which the coalfields are bounded might then have been initiated.

The depression which followed the long period of denudation would produce serious compression which would cause more or less important flexures of the rocks by some of which the coalfields would be reduced in area owing to the upturning of the rims and the formation of anticlinals and synclinals within.

ORGANIC REMAINS FOUND IN THE ROCKS

The remarks under this head will be confined to a short notice of the animal remains, the argument being unaffected by the vegetable remains.

E. Hull[19] in a paper on "The Upper Limit of the Essentially Marine Beds of the Carboniferous System in the British Isles," says: "33 out of 53 species of marine shells pass from the Carboniferous limestone upwards into the Gannister beds, while only five pass up into the middle coal measures."

In the middle and upper measures the most abundant shells belong to the Genera *Anthracoptera*, *Anthracomya* and *Anthracosia*, which are usually considered to indicate estuarine and perhaps fresh water conditions, although in the lower measures of the Lancashire coalfield they are found in association with distinctly marine genera, such as *goniatites* and *aviculopecten*.

Fish remains were found by James W. Davis[20] in a bed of cannel coal between Morley and Adwalton, near Leeds, and more particularly in the impure cannel above and below it. They were both elasmobranchs and ganoids, but much of the most common was *coelacanthus lepturus*.

From the cannel coal of the South Lancashire field some good remains of fish belonging to the genera *Megalicthys*, *Holoptychius and Ctenoptychius* have been obtained.

The change from marine conditions during the deposition of the lower coal measures to estuarine and perhaps fresh water conditions, whilst the other measures were being accumulated

[19] Brit. Assoc. Report, 1878.
[20] Brit. Assoc. Report, 1878.

was probably due to compressive stress imposed upon the rocks during the submergence which preceded or occurred during upper coal measure times, by which the rims of the basins would be turned up so as to stand out above the sea in such a way that the latter could only gain access to the basins at certain times as, for instance, during high tides. As it is practically certain that the area occupied by some of the coalfields underwent a submergence during the time the upper measures were being laid down it may seem unlikely that estuarine or fresh water conditions could have been maintained in the way just suggested, but it must be borne in mind that it was submergence that caused the compression, and therefore as long as the former continued the rims of the basin would rise.

From the investigations of G. H. Darwin[21] it is practically certain that the tides in Carboniferous times were much higher than they are to-day and more frequent; he says: "When the tides were twice as high as at present there must have been 19 or 20 of our present days in the month instead of 27 1-3 as at present, and there would be about 38 neap tides in the year instead of about 26."

How much higher the tides were in Carboniferous times than now we do not know. The rocks formed from the dawn of geological history to the close of the Carboniferous period are estimated to have a thickness in Britain of about 95,000 feet. From the latter time to the present about 18,000 feet were laid down. But these figures do not afford any clue as to time, actual or relative, because if the tides have been decreasing in volume and frequency ever since the moon initiated them, tidal work, over any given period, must have been decreasing also, for the denuding effects of tides is largely dependent upon the winds which, owing to the decreasing rate of the earth's rotation, would be gradually reduced in velocity. These—then more powerful—agents may have been concerned in the formation of coal-beds in a way not usually thought of. We see coal seams close together in one part of a field, and in another separated

[21] On the Geological Importance of the Tides; Nature, Vol. XXV., p. 213.

by much rock, or, one seam is thick, another thin. Why? The answer will probably appear in the sequel.

FACTS OPPOSED TO GROWTH 'IN SITU'

It is stated by Bischof in his "Chemical Geology", vol. I., that: "The conversion of vegetable substances into coal has certainly been effected by the agency of water."

And this is so readily acknowledged by those who favour the idea of the precedent vegetable matter having grown on the spot that the Carboniferous forests are assumed to have been akin to the swamps at the estuary of the Mississippi—practically level.

On the above view, in the case of such seams as the Thick Coal of South Staffordshire and the Main Band of the Cumberland coalfield as well as similar seams in other fields, part of the earth's crust with a layer of vegetable matter on it would have to sink at an increasing rate from a certain line across the respective field, which line may be looked upon as the hinge of a huge horizontal door. On the hinge side the door would retain its level, but on the opposite side it would be lowered for a certain distance and the wedge-like space above—between it and the water level from which the door had sunk—would be filled with mud and sand, from the upper surface of which other forest trees would have to spring. This process in the case of the Thick Coal would have to be repeated nine times. We have no experience of the kind of movement involved in the operation assumed, and I think it is most unlikely to have occurred. But further, the assumption of those who hold that view is that the rock underlying a coal seam formed the soil in which the antecedent plants grew. When that rock is fireclay, the assumption is fairly plausible, at first sight, but if the underlying rock is shale or sandstone the idea is not so satisfactory, for it is unlikely these latter rocks ever formed the surface soil of a forest. Again, close up to the supposed hinge, in the case of any of the split up seams, there is not space for fireclay. In the undivided part of the seam none was needed. We may there find a thin parting of shale or sandstone—an

inch or two thick—but not sufficient to support huge trees like those found near some coal seams, even if the character of the material had been otherwise suitable. In order to convert such materials into soil capable of sustaining forest trees, it would have to be raised above the surface of the water and exposed to meteoric agencies. To produce, in the manner above indicated, a coalfield containing sixty seams of coal there would have to be that number of sinkings, each followed by a small rising. In the majority of cases, the sinkings would have to be of a gyratory nature—a complication which to my mind renders growth *in situ* most unlikely.

If it be assumed that the tree-trunks found standing out from the upper surface of coal seams had been rooted in the underlying rock, whether that be fireclay, shale or sandstone, we are met with the difficulty that they must have been of such a height—considering the amount of compression undergone by vegetable matter during its conversion into coal—that it is quite unlikely they could remain erect during the extended period required to form a layer of vegetable matter thick enough to yield, say, a six-foot seam of coal, like the uppermost seam in Fig. 2. But it is often found that these trunks thicken suddenly near the upper surface of the seam over which they occur, as in Fig. 3, just as forest trees do near the ground, a fact which suggests that these buried trunks were broken off close to the ground. For the reason already given, it is unlikely the root stock of these trees was buried in the seam below and converted into coal.

The thin shale partings—often less than an inch in thickness —so common in coal seams, are altogether opposed to growth *in situ*. They extend in regular planes over large areas, with little variation in thickness, in a way they could not possibly have done if the shaly or sandy matter composing them had been deposited among growing trees, as is suggested by those who believe in such forests.

FACTS FAVOURING A DRIFT ORIGIN

The thin shale partings and the erect tree-trunks are facts paralleled by those found in the so-called submerged forests

occurring along the Cumberland coast, which are undoubtedly of drift origin.

The splitting up of seams and the expansion in wedge form, of the intervening strata—as in the thick coal of South Staffordshire—is easily explained on the drift theory. Let it be assumed that the bottom of a partly filled basin had a form like that shown by the line *a b* in Fig. 19.

Fig 19.

Drifted vegetable matter might be deposited more or less evenly on this surface. After a time let it be supposed that there was a partial or total cessation of vegetable deposition and that argillaceous or arenaceous matter, or both, accumulated over it, the source of the earthly materials being to the right of *b*, and the suspended matter reaching no further toward the left than *c*. The basin being deeper at *b* than at *c* and nearer the source of the muddy current, more sedimentary matter would be deposited at the former than at the latter point where, in accordance with the assumption made, the matter held in suspension was so small that the deposit might be less than an inch. The deposition of vegetable matter being resumed, a second layer of coal-forming material would be deposited which, between *a* and *c* would rest directly on that previously deposited, or be separated from it by a very thin parting only, whilst between *c* and *b* the new layer would be separated from that formed earlier by sand or mud increasing in thickness toward *b*, and so for other layers until there might be produced a section in which a seam was split as shown in Fig. 19.

The occurrence of erect trunks is easily understood from what has been already said in connection with so-called sub-

merged forests and the partially submerged trees seen in the Upper Arrow lake.

The burial of fish in seams is also easily understood, although their preservation, in some of the circumstances attending the deposition of the vegetable matter and the chemical and physical change undergone by the latter, may not often have been possible.

WHY THE DEPOSITION OF VEGETABLE MATTER WAS INTERMITTENT

We now approach a more sepculative part of our subject because there is much less data to guide us. Vegetable matter was deposited at various times and in different quantities, the beds being separated by more or less argillaceous or arenaceous matter, or both. What is the meaning of this intermittence? If we look at a map of the world on which the important coal deposits are shown, it will be seen that they occur, both in the Northern and Southern Hemispheres, within the regions of the anti-trade winds. Let us next carry our minds back to Carboniferous times when the earth was rotating on its axis more rapidly than it is to-day, and when, as a consequence, the winds would have more force and the tides greater denuding power. It is also practically certain that at that stage of the earth's evolution the average temperature of the crust would be many degrees higher than it is now. Therefore evaporation would be more rapid, rains heavier and more frequent, rivers larger and floods higher, so that in addition to the increased denuding action of the tides, there would be more work done by rain and rivers. Imagine a number of large rivers flowing into the future coal basins through wide-bottomed valleys and the whole of the land surface covered with a luxuriant growth of forest trees and ferns, etc. Although the average winds would, in those days, be stronger than the ordinary winds of to-day, yet gales of extreme violence would, as now, occur in most cases at more or less distant periods. But when they did take place they would in consequence of their greater power, cause enormous destruction—tearing up trees by the roots or breaking them off

at weak parts of the stems. Heavy rain-storms following these gales and flooding the low-lying, wide-bottomed valleys would carry off the fallen timber in enormous quantities into the water-filled basins. That timber would float about on the surface, some probably below it, according to the quantity there was of it, for some considerable time, until it became water-logged; then it would sink and form a layer of more or less uniform thickness over the bottom. All the time muddy and sandy matter would be deposited—during rain-storms much more rapidly than at other times. The root-stocks with some of their soil adhering would sink some time before the broken off trunks and would become buried in the underlying muddy matter. As they would sink with the stump of stem pointing upwards, they would seem, when buried, to be in the position of growth. They cannot, however, be where they grew, for they are scattered indifferently through the fire-clay and not along the upper part of it, as they would have been if the fireclay, or other rock immediately underlying the coal, had been the soil in which they grew. When the floating timber had become water-logged, it would sink so rapidly that the layer formed by it on the bottom would be very little contaminated by subsiding mud. It might be that the blown timber could not all be removed by one rain-storm or even two, in which case a layer of mud might be deposited on the vegetable layer last formed, before a second layer of woody matter was superimposed, and so for other layers. The longer the interval between destructive wind-storms, the further apart would the coal seams be, and the greater the storms, the thicker the seams.

In the case of the lower measures, where the coal seams are usually much less numerous than in the middle measures, it may be that a large part of the timber escaped out to sea before the basins were less isolated than they afterwards became. In the case of the upper measures it is possible that upturning of the rims by lateral pressure might so alter the contour of the land that only some of the smaller streams entered the basins, the larger ones being so diverted as to enter the sea.

DEVELOPMENT AND IMPROVEMENT OF BREATHING APPARATUS

By H. H. Sanderson

(Western Branch Meeting, Nanaimo, June, 1919.)

Self-contained breathing apparatus, more often called 'rescue apparatus,' is designed for the purpose of saving life and property when endangered by fire, smoke, fire-damp or other poisonous gases, either above or below ground. The portable apparatus is one which enables the wearer to penetrate the irrespirable gases without being supplied with air from any outside source. It is therefore essential that such apparatus should provide the wearer, in these circumstances, with good air, by continuously rendering the exhaled air fit for reinhalation, that is to say, it must be provided with means for renewing the consumed oxygen in a continuous manner and in sufficient amount, besides making harmless the carbon dioxide produced in the lungs. At the same time the apparatus must not form a hindrance in the performance of work.

Breathing apparatus of the self-contained type was first introduced into the United States in 1907, following which the Proto, Draeger and Westfalia apparatus were installed at various mines and plants throughout the United States and Canada. The Proto apparatus was manufactured in England, while the latter types came from Germany. Little change has been made in the Proto apparatus up to the present time, although several more or less important improvements have been made on the Draeger. The Westfalia did not meet with great success, and the sale of this type was soon abandoned.

Importation of these types of apparatus continued until 1914, when it became necessary for the American representatives to manufacture them for themselves. Considerable difficulty was experienced in this work for some time. Investigations conducted by the United States Bureau of Mines demonstrated very forcibly that there was considerable room for improvement in the various types of European made apparatus, and the

work was commenced by the various engineers, physiologists and chemists of the Bureau of Mines for the development of an improved type of oxygen breathing apparatus which will be referred to later in this paper.

Before taking up the question of improvements on the various types of apparatus let us look for a few minutes at the principal defects in the three types previously mentioned. In January, 1917, the United States Bureau of Mines published Technical Paper No. 82, written by Yandell Henderson and James W. Paul. The purpose of this publication, or report, was to supply information regarding the relative merits and defects of the various types of apparatus then in use. With this in mind I trust that I may be pardoned if I quote from this report, for I feel that after the thorough investigation which these men made, no one is better qualified to present this matter to the public, and so in pointing out the limitations of the apparatus in use in 1917, I will use their report.

In developing self-contained breathing apparatus the real problem is not only to make an efficient and reliable device, but also to fit it to the peculiar and varying needs of the wearer. It is important if a man is to wear breathing apparatus for even a few minutes, and essential if he is to depend on it to keep him alive for several hours, and do also considerable work, that the condition in his lungs should be essentially similar to those when breathing normal air. The apparatus must adjust itself to the respiratory needs of the wearer, and also to wide variations in these needs. Until recently, however, the wearer has been expected to adjust his breathing to the apparatus. To forget, or fail to do this even for a few minutes, might cause his death.

One of the principal defects of former types of rescue apparatus as usually arranged, was that the oxygen supply was set at a fixed amount per minute, and that this amount, although more than sufficient to cover the requirements of the wearer while resting, was quite insufficient to allow him to make vigorous physical exertion.

Oxygen is often spoken of as a food. In one sense this is correct, but the demand for oxygen differs from the demand for food in the fact that the supply of oxygen must be continuous. A man may go without eating for several days, and still be able to do considerable work. After being properly fed he may be none the worse for his experience. Conditions as regards the oxygen supply are far more peremptory. The amount that the body uses in any one minute it needs and must have within that minute, or at least during the next succeeding minute. Even a slight deficiency in oxygen impairs intelligence and judgment, and produces almost immediately a condition of intoxication or delirium, rendering the subject incapable of intelligent action and paralyzing the muscles so that he cannot stand or walk. If this deficiency is continued for even a few minutes serious and often permanent injury to the nervous system (or even death) results. These considerations have not heretofore been adequately taken into account.

This insidious effect of breathing air deficient in oxygen cannot be over-emphasized. The symptoms are in practically all respects identical to those of breathing carbon monoxide, and in some respects resemble those of alcoholic intoxication. The peculiar danger in breathing such air lies in the fact that discretion and judgment are quickly impaired. Moreover, in many individuals, perhaps in most men, the breathing is at first so little affected that the man remains unwarned of his danger until his legs give way and he falls helpless.

Next in importance to a sufficient supply of oxygen is an efficient arrangement for absorbing from the air in the apparatus the carbon dioxide that the wearer produces. One of the most important facts demonstrated by recent advances in physiology is that in normal men and animals, under ordinary conditions, the amount of breathing is principally regulated, not by the oxygen consumption, but by the carbon dioxide produced. For this reason it appears improbable that any apparatus, with which the wearer will not do any rebreathing whatever, for use in poisonous gases can ever be devised for use for more than a few minutes at a time. It is especially important, therefore, that the

alkali should be so arranged as to absorb as completely as possible the carbon dioxide exhaled by the subject into the bags before he again inspires the air.

In the former types of Draeger and in the Westfalia apparatus the expired air was drawn through the absorber and into the inspiratory bag by means of an injector through which the oxygen enters the circulation system. Natural circulation—that is, movement of air produced by the subject's breathing, as in the Fluess-Proto apparatus—is to be preferred to automatic circulation induced by an injector. One particular advantage of natural circulation is that if the wearer happens to become imprisoned in 'bad air' he can make his oxygen supply last for many hours by turning off the fixed feed on the oxygen cylinder and using the by-pass at intervals to supply the relatively small oxygen consumption during rest hours. Otherwise the supply would run out at the end of two hours, and the man might lose his life. With apparatus of the automatic circulation type, such conservation of oxygen is impossible, for turning off the oxygen feed stops the absorption of carbon dioxide and makes the breathing much harder.

No subject in regard to rescue apparatus has been more debated than the use of the helmet. Many practical mining men insist that the helmet is advantageous in that it allows the wearer to speak more distinctly and to breathe through the nose, a more natural method of breathing than with the mouthpiece and nose clip. It necessitates the wearer's breathing into a 'dead space' greater than the volume of an ordinary deep breath. The air that the wearer expires into this space he is obliged, in great part, to reinspire from it. The defects of the helmet are serious, but the greatest objection to its use is the danger of leakage. I am glad to say at this point that the officials of the British Columbian Government, realizing the inefficiency of the helmet, were among the first to install the mouth-breathing apparatus.

The importance of having all valves, tubing, and openings as large and as free from resistance as possible has not, until recently, been adequately appreciated either by the manu-

facturers or users of breathing apparatus. When one puts on any of the three types of apparatus previously mentioned, he finds that he can breathe quietly back and forth into the bags without noticeable effort. Even if directed to breathe vigorously for a few seconds, most subjects declare that they feel no considerable resistance. If, however, the wearer is required to exert himself so vigorously as to induce heavy breathing, he finds a resistance so exceedingly annoying that it soon occupies his mind to the exclusion of everything else, and he is strongly tempted to tear off the apparatus.

Safety demands that when the wearer of an apparatus is surrounded by an atmosphere containing poisonous gases there should be no leakage inward. With the injector type of apparatus it is particularly important that no negative pressure should occur at any point where the outside atmosphere may be drawn in. As formerly constructed the injector of the Draeger drew air through the absorber. In case the absorber or the tube leading to it was cracked, poisonous gases could enter. A life has been lost in this way. This defect has been to a considerable extent remedied by so placing the injector of the Draeger apparatus that the air is forced through the absorber under a slight positive pressure. In any arrangement of this sort, however, there must always be a greater or less area of negative pressure on the side from which the injector draws. This is an additional reason for abolishing the artificial circulation and giving up the injector entirely. A natural circulation depending upon the respiratory movements of the wearer is altogether preferable.

It is an advantage to have a slight positive pressure in the apparatus, although it must not of course be of such amount as to impede the wearer's expiration—about 0.5 centimeter, or at most 1.0 centimeter, water gauge. Even the best constructed apparatus is liable to leak slightly, and all leaks should be outward instead of inward. One of the principal reasons for recommending a greater supply of oxygen in the apparatus of the fixed-feed type is the fact that there will then be a continual slight leakage of the excess outward. On the other hand,

when the supply is insufficient, and the breathing bags are sucked flat at each breath, the negative pressure so produced may draw in the surrounding poisonous atmosphere.

As regards joints and connections of these three types of apparatus, the Fluess excels both the Draeger and Westfalia. The many joints on the Draeger apparatus require careful inspection to insure their being made fast. Screws having a cross arm for turning admit of making the joint reasonably tight, but thumb-screws with a circular milled head are not so reliable, as a heavy glancing blow will often loosen them. Such screws have frequently been found loose both in training and in actual rescue work. In many instances loosening has been due to the metal part of the tube not having a locked seat, and in consequence a slight movement of the metal part has worked the screw loose.

The reducing valves of the former types of apparatus also were frequently a cause of trouble, as a result often of the deterioration of the rubber diaphragm. One of the most serious difficulties in the way of devising and constructing a reliable mine rescue apparatus is the necessity of using rubber. So-called pure gum rubber remains soft and elastic in Europe for months, but in the dry and brilliant climate in which most of the American mines are located it becomes stiff and brittle in as many weeks. It appears at present impossible to avoid entirely the use of rubber, but it is evident that the parts composed of rubber should be as few as possible.

Impelled largely by the observations made by Doctors Henderson and Paul, the Bureau of Mines undertook to develop a breathing apparatus that should embody the recommendations of these men, and consequently in 1914, W. E. Gibbs, a mechanical engineer of experience and skill especially suited to the task, started, with their assistance, to design what is now known as the Gibbs apparatus.

Two years later, during a period while Mr. Paul was not connected with the Bureau of Mines, and while he was associated with Mr. Clarence Hall, who had previously left the Bureau of

Mines service, he took out the patents on the details of construction of an oxygen breathing apparatus which is now known as the Paul apparatus.

Both the Gibbs and Paul apparatus have now been perfected, and placed on the market. The machines show considerable improvement over the former types. In the first place the former type of fixed flow reducing valve has been replaced by a feed which delivers the oxygen to the wearer as it is required. The efficiency of the regenerating cartridge has been greatly increased, and the circulation throughout the apparatus is maintained at a practically normal rate.

The use of the helmet has been discontinued in favour of the mouthpiece, which is a decided improvement over former types of mouthpieces in that the breathing is much easier and the saliva is readily disposed of.

The danger of negative pressure has been eliminated and the outlet openings on the reducing valve of the Gibbs apparatus have been considerably enlarged. There are no rubber parts in or around the valve to deteriorate. The number of working parts and connections has been reduced to a minimum, and the use of rubber has been cut to the very smallest possible amount. Simplicity means safety. The weight of the Gibbs apparatus has also been reduced to 35 pounds.

Through an act of Congress, approved Feb. 25th, 1918, the Bureau of Mines undertook to establish a schedule for the official test and approval of breathing apparatus. This schedule, known as No. 13, was first published in March of this year, and the Bureau is now engaged, at their testing station in Pittsburgh, in testing apparatus for approval. According to this schedule (No. 13) all breathing apparatus which passes their test and requirements will carry an approval plate marked as follows:—

"PERMISSIBLE MINE RESCUE BREATHING APPARATUS U. S. BUREAU OF MINES. APPROVAL NO. ——."

In conclusion, let me say that never in the history of breathing apparatus in this country have there been such marked improvements as in the last eighteen months. This has been brought about principally by the work of the Bureau of Mines and also by the urgent call received from General Pershing for 500 sets of Gibbs apparatus for service in France, the Gibbs having already been perfected by the Bureau.

It is hoped that the possibility of having approved apparatus on the market in the near future will do much to increase the confidence of mining men in the use of such equipment, and also to stimulate interest in the training of men to wear the apparatus when the occasion demands.

REGRADING SLOPES, No. 4 MINE, CUMBERLAND, B.C.

By Charles Graham

(Western Branch Meeting, Nanaimo, June, 1919)

No. 4 Mine of the Canadian Collieries (Dunsmuir) Limited, Cumberland, is situated on the shores of the Puntledge lake about 2½ miles west of the city of Cumberland. This mine is one of the oldest operating mines in the province; and what is known as the 'lower seam,' which outcrops in the bluff overlooking the lake, is worked by two slopes driven in the seam. No. 2 slope branches off from No. 1 slope about 50 feet from its mouth at an angle of 45°. The seam pitches about 8°. In No. 1 slope, at a short distance from the surface, the seam flattened out and ran level for a distance of 750 feet. In No. 2 slope, it went upward for a short distance and then resumed its normal pitch.

In order to get the 'empties' over these 'flats' near the surface tail-ropes were necessary. The slopes were operated by a 4-drum main and tail-rope hoist driven by a 350-H.P. motor. Two friction clutch drums on a common shaft were used for main ropes and two on another shaft for tail-ropes. The main and tail-rope drums for each slope were tandem and were connected by a connecting rod to discs on each shaft.

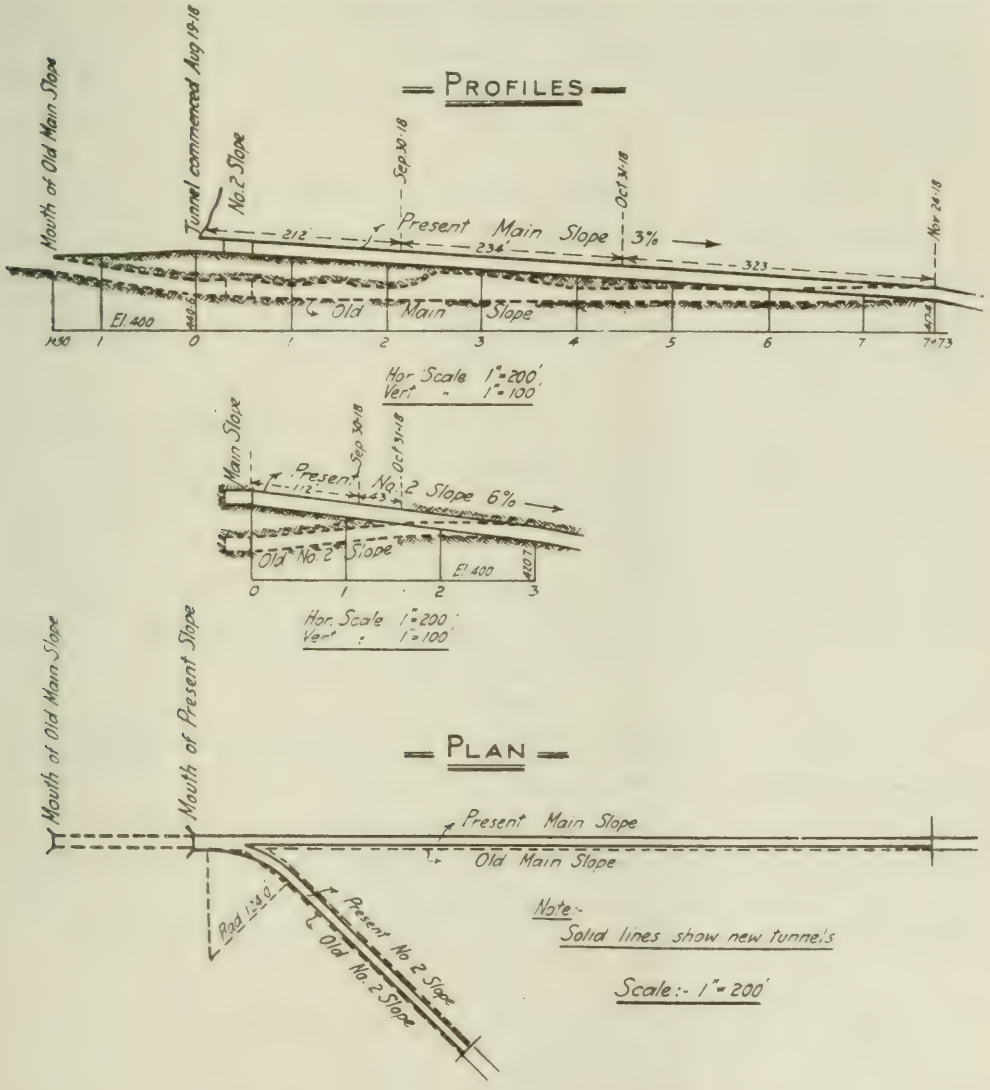
Each slope has a separate track leading from the tipple into the mine. Hoisting can be carried on from both slopes simultaneously.

Bull wheels were used on each slope at the inside end of these 'flats', and, on each slope a man was stationed to attach and disconnect the rope. Seven thousand feet of rope was required for tail-rope for the two slopes.

As the tail-ropes involved considerable operating and maintenance expense it was decided to regrade these slopes so as to provide a grade in favour of the 'empties' throughout the entire length of the slopes. In order to do this a new tunnel was driven, starting directly over the old tunnel, at a height which would give continuous grade in favour of the 'empties.' This new

tunnel was commenced in sandstone overlying the seam, there being at the point 15 feet of strata between the roof of the old slope and the floor of the new one.

The distance to be driven in No. 1 slope was 575 feet, and in No. 2 slope 155 feet. The first 50 feet of tunnel to the point where No. 2 slope turned off, was driven 14 feet wide and 7



feet high. From this point the slopes were driven 10 feet wide and 7 feet high, the outer rib lines being carried in both slopes. No. 2 slope was turned off on a curve with a radius of 124 feet.

Work was commenced on August 19th, 1918, and No. 2 slope, being much the shorter, was completed on October 7th, with the exception of the final connection which could not be made until the outside arrangements were completed.

Both slopes were driven as solid tunnels until the timbers of the old slopes were reached. All rock had to be blasted until there was slightly less than 2 feet of strata between the floor of the new slopes and the timbers of the old slopes. Broken ground was then entered, and 'shooting' in the bottom became necessary.

In drilling and 'shooting,' the general method followed was to drill all 'breakers' or cut holes as near the roof as possible, and then take up the bottom with lifting shots. The timbering in the old slopes was strengthened by centre posts and additional stringers were put in where required.

When the roof of the old slope was reached the roof 'brushing' was continued on top of the timbers until only about 60 feet remained to be completed. This was 'brushed' through during the week-end and the tracks changed from the old to the new slope on No. 1 side. During the following week-end No. 2 slope was 'brushed' through and the tracks changed. The work was completed on November 24th, 1919.

To connect the new opening to the tipple a new approach had to be built. This was erected astride the old one, which had previously been filled in with rock, and was continued until there was just room for the cars to pass underneath from the old slope. This approach was completed and connected to the tipple at the same time as the change was made in the mine.

The remarkable feature of the work was that not a minute's time was lost in the operation of the mine. The slopes were hoisting coal sixteen hours per day, during the whole of the time that three shifts were employed on the new work. At no time did the tunnel break through on the slopes below until the timbers of the old slopes were reached.

A new tipple has also been erected at this mine. In the old tipple the coal was dumped by a Philips cross-over dump on to bar screens; the slack went directly into railway cars, and the lump coal was discharged on to an apron conveyor which was used as a picking table. The new tipple was built alongside the old one. A three-car rotary dump, which discharged the coal on to a Marcus screen, was installed. This screen is used as a combined screen and picking table. The slack goes directly into railway cars, as also does the lump from the end of the Marcus screen. Only two grades of coal are made at the tipple, the slack going to the washery, where it is washed and graded.

NOTES ON OPERATING CONDITIONS OF THE LETHBRIDGE COLLIERIES

By Moses Johnson

Operating conditions in the Lethbridge collieries are, in certain respects, less favourable than those in other producing coalfields in Alberta. The cost of shaft sinking, equipment and maintenance, to a depth of from 400 to 600 feet in the mines of the Lethbridge district is, for example, considerably greater than in the mines of the Drumheller field, which is the most important producing area operating in competition with the Lethbridge collieries. The cost of shaft sinking alone in three of the largest mines of the Lethbridge field represents a very large capital expenditure, and the cost of shaft equipment and charges for maintenance are correspondingly great. The following figures for depths and cross-sections of shafts measure in a general way the capital outlay required to reach the producing coal seams:

Depth and Size of Winding Shaft, Return Airway.	Depth and Size of Shaft, Intake Airway.	Cage.	Guides.
No. 6 Galt			
400′x20′x21′	400′x10′x20′	Double, 17′x5′	4 per cage, 7″x9″
No. 3 Galt			
301x′10′x18′	100′x10′x10′	Double, 9′x4½′	2 per cage, 6″x8″
Chinook			
440′x8½′x17′	440′x8½′x12′	Double, 9′x4½′	2 per cage, 6″x8″
Coalhurst			
576′x20′x24′	576′x10′x20′	Double, 17′x5′	4 per cage, 6″x8″

It has been necessary to leave comparatively large pillars for the protection of these shafts, and this in turn has involved considerable extra cost because of the amount of narrow work required. The large shaft bottoms have also been relatively expensive. The surface winding equipment required for operation of these comparatively deep shafts is proportionately large. With the exception of the Chinook mine, all second shafts are provided with hoisting equipment. Long air lines of large capacity are required for operation of the pneumatic punching

machines in use at the Lethbridge mines. The total power requirements for operation of surface winding engines, air compressors, rope haulage system, etc., are heavy, necessitating a boiler plant of large capacity.

Underground conditions are not altogether favourable; the seam varies in thickness from 3 feet 10 inches to 4 feet 3 inches, and is undulating and broken by numerous faults. The roof is only fairly good, and the ground above is heavy. Gas is encountered in small amounts, particularly at the faults.

An average section from the surface to the main seam at No. 6 Galt mine shows: 8 to 10 feet clay and gravel surface soil; 170 to 200 feet gumbo; 16 to 20 feet gravel; 170 to 200 feet short grained shale; 6 inches coal; 8 to 12 feet shale; 6 to 8 inches coal; 14 inches shale and 4 feet coal. From these figures it will be noted that there is a comparatively light cover of shale between the seam and gumbo above. At this mine there is considerable difficulty in maintaining roads and working places, due to disturbances of the gumbo following slight settlements below. The timber consumption averages from 10 to 12 lineal feet per ton of coal mined.

Very heavy pillars are left for roof support, involving considerable expenditure for narrow work. This practice of leaving large pillars results in the rapid advance of the workings, thus demanding an extensive rope haulage system. At this mine an endless rope system is in use; from 6 to 7 miles of $1\frac{1}{16}$ in. rope are required. This haulage system is operated by a 300 H.P. steam engine situated on the surface. During periods of reduced production the maintenance of roadways and working places involves considerable expense.

At the No. 3 Galt mine 75% of the present working places have a fair roof and are under comparatively light cover, being located below the flats of the river bottom. Timbering costs in the present workings of this mine are therefore much lighter than those of No. 6 mine, although the older workings of No. 3 mine were under heavy cover and required extensive timbering. Water is one of the chief operating difficulties of

No. 3 mine. At one time twenty-eight air driven pumps were in use; a number of these were later replaced by four electrically operated turbine pumps, one of 40 H.P. and three of 50 H.P. each. For nine months of the year the daily average water pumped amounted to over 1,000,000 gallons. For three months of the spring season a pumping capacity of 2,000,000 gallons daily is required. The No. 3 mine is equipped with an endless rope haulage system, similar to that of No. 6. From 4 to 5 miles of ⅞ inch rope is required for the present haulage system, which is operated by a 250 H.P. steam engine.

At the Chinook mine, roof conditions are better than in the mines referred to above. A thin stratum of shale (about 8 inches) lies between the top of the working seam and a second thin coal seam above. This shale is broken down, and the upper thin coal seam, which is overlain by a poor shale cover, is maintained as a roof. This coal cover breaks easily and timbering must be kept well up to working faces. If the coal roof is allowed to break down, thereby starting the shale cover above, very heavy timbering is necessary.

Haulage conditions at this mine are much more difficult than in the mines formerly described. The seam has a pitch of approximately 6% a distance of 500 feet from the shaft bottom, in the direction S. 64° W., and varies thereafter from 2% to 4% in the same direction. A slope has been driven in the seam and is equipped for hoisting purposes. (100 H.P. electrically operated hoist.) It is expected that when this slope has been driven a further distance of from 600 to 800 feet conditions similar to those of No. 6 Galt or Coalhurst mine will be met. There is approximately 250 feet of shale cover above the working seam of this mine before soft ground is reached.

At the Coalhurst mine, roof conditions are still more favorable. The overlying shale is stronger and carries better than in the mines previously mentioned. In places there is 325 feet of shale between the working seam and soft ground above. Disturbances due to settlements in the workings are taken up in the shale strata, without starting movement in the ground above.

Haulage conditions in this mine are in general similar to those of No. 3 and No. 6 Galt, with the difference that three separate rope systems are in use, driven by three electric motors located at the shaft bottom. One of these motors is of 30 H.P. and two of 40 H.P. capacity. The Lethbridge seam is undulating and considerable grading is required for haulage roads. The seam is characterised by frequent faults; these are most numerous in the workings of the Chinook mine. Displacement varies from 1 to 25 feet. The majority of the main entries are driven on the four entry system and these run through the faults. This practice involves further grading in building haulage roads. Such grading work made necessary by the undulations and faults of the seam, requires a constant force of several men and adds a considerable item of cost to operating charges.

No. 6 Galt mine has from 20,000 feet to 25,000 feet of four entry system driven, totalling approximately 100,000 feet, exclusive of crosscutting, butt entries and room necks, all of which is narrow work.

Closed lamps (Edison and Wico types) have been adopted at the Chinook, Coalhurst, and No. 6 Galt mines, because of the small amounts of gas encountered at faults and when drawing pillars. The Wolff lamp is used by all officials. Provision for ventilation at these mines is indicated below:

		Cubic feet per minute.	W. G. in inches.
No. 6 Galt	Sirrocco Fan Blowing.	204,000	2½
No. 3 Galt	Capell Fan Blowing	81,000	4
Chinook	Sullivan Fan Blowing.	60,000	⅞
Coalhurst	Walker Fan Blowing.	142,000	2¼

At each of these mines a spur track has been built by each coal company. This construction has involved considerable outlay, and transportation on these spurs adds to total operating costs of the mines.

Comparison of operating conditions in the Lethbridge district, as roughly outlined above, with those met with in the

Drumheller field, is very much in favour of the latter. The Annual Report for the Province of Alberta for 1917 states that in the Lethbridge district 4.4. feet of round timber and 3.2 feet B.M. of square timber are used per ton of coal mined, as against only 2.2 feet of round timber per ton of coal mined in the Drumheller field. The mere cost of timber, quite irrespective of handling and setting it, is thus a large expense item at the Lethbridge mines, while it affects those at Drumheller in much less degree. The one and great advantage of the Lethbridge field is that the coal is of good quality, being 10% to 13% better for storage purposes than Drumheller coal, and, on the average, about 10% better in quality.

SOME NOTES ON THE SAMPLING OF COAL MINE AIR

By Dudley Michell

(Western Branch Meeting, Nanaimo, B. C.).

During the past year, the British Columbian Department of Mines has been conducting tests with the 'Burrell Gas Detector' to demonstrate its accuracy in determining the percentage of methane in coal mine atmosphere.

Briefly described, the detector is a portable apparatus weighing about three pounds, into which is drawn a sample of the mine atmosphere travelling at the point of sampling. The methane being burned out of the mixture by electricity, the percentage (which is determined by the falling of the water level due to shrinkage caused by the methane having been burned off) is observed on a graduated scale.

As a result of the tests it was considered reasonable to adopt the detector in question as the apparatus approved by the Chief Inspector of Mines (as required by "Coal Mines Regulation Act") for determining smaller percentages of methane than can be determined in the ordinary safety lamp.

At the time of sampling with the detector, a check sample was taken with the regular vacuum bottle. This was analysed in the Dominion Government Laboratory in Ottawa, and, in addition, note was taken of the 'gas-cap,' if visible, in a round-wick Wolf safety lamp.

There were 149 samples taken with the detector, and checked by chemical analyses. The average of the results showed 1.1% of methane for the detector, and 1.17% of methane as determined by chemical analysis. In other words, the variation between the results given by the detector and chemical analyses respectively covering 149 samples, was .07% only. The maximum range of difference for any one sample was not more than 5%. It must be remembered that the gas content is read in

tenths of one per cent on the detector scale, whereas in the chemical analysis it is reported in quantities as low as one-hundredths of one per cent.

HEIGHTS OF GAS-CAPS AND RELATIVE PERCENTAGE OF METHANE

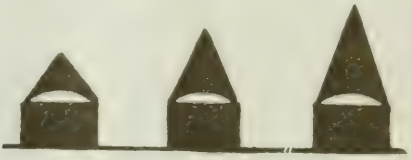
The following chart gives the average height of 'gas-cap' and percentage of methane in the return air of the Crowsnest Pass and Coast collieries of British Columbia, as determined by over 50 check samples. The samples were taken by various mem-

Crowsnest Pass Collieries

Trace	*Small cap*	1/8"	1/4"	5/16"
1.09%	1.41%	1.68%	2.12%	2.50%

bers of the inspection staff and not by any one individual. Due allowance was made for the height of the 'fuel-cap,' shown on the safety lamp.

Coast District, Comox Colliery.



1/8"	1/4"	3/8"
1.08%	1.72%	2.08%

It will be noticed that there is a difference in the average height of the 'gas-cap' for the same percentage of methane in the return air of mines of the Crowsnest Pass and Coast collieries.

According to recognized textbooks on the subject of mine gases, it has been generally understood that .4 of an inch cap equals 1.5% of methane and that .6 of an inch cap equals 2%, but from the tests conducted by the Department it shows on an average that 1.5% methane is represented by 1/4 of an inch

'gas-cap' if in the Coast collieries, and by 1/8 of an inch 'gas-cap' in the Crowsnest Pass collieries, and that 2% of methane gives 1/4 of an inch cap in the Crowsnest Pass and 3/8 of an inch cap in the Coast collieries. Whether or not the change of barometric pressure plays much part in the variation between the district averages requires careful study.

It will be observed in the following table that there is a noticeable difference between the oxygen content of the various district samples, and more especially does this apply to the incombustible gases, namely carbon dioxide and nitrogen. It will also be observed that there is nearly 1% more combustible gases in the return air from the Crowsnest Pass collieries than in those of the Coast collieries.

OUTFLOW OF METHANE

Average analyses of coal mine air samples taken in British Columbia during 1918:

District	Average of	Chemical Analysis CO_2	O	CH_4	N
Crowsnest Pass	187 Samples	0.12	20.45	1.09	78.34
Nicola	20 "	0.13	20.58	0.10	79.19
Coast	212 "	0.23	20.28	0.41	79.08
Total Province	419	0.16	20.43	0.53	78.87

Average outflow of methane per day (24 hours) in mines on various coal seams of the province:

					Cubic feet of Methane each mine per 24 hrs.
Average of	128	samples	taken from	Coal Creek seams	649,380
"	61	"	"	Michel	427,152
"	4	"	"	Corbin	120,600
"	3	"	"	Princeton	78,240
"	14	"	"	Merritt	32,989
"	48	"	"	Wellington	30,301
"	89	"	"	Douglas	99,834
"	70	"	"	Comox	450,539
"	417	"	"	All	236,129

Average amount of methane given off per ton of coal mined, in mines on various coal seams of the province:

					Cubic feet of Methane per ton of coal mined
Average of	117	samples	taken from	Coal Creek seams	2,002
"	57	"	"	Michel	2,727
"	4	"	"	Corbin	448
"	3	"	"	Princeton	1,717
"	14	"	"	Merritt	280
"	50	"	"	Wellington	208
"	88	"	"	Douglas	392
"	68	"	"	Comox	1,171
"	401	"	"	All	1,040

These samples were computed from 28 operating coal mines. It will, therefore, be seen that on an average there is 236,129 × 28 = 6,611,612 cubic feet of methane per day (or the equivalent to produce slightly more than 250,000 indicated horse-power per day is expended into the atmosphere by the coal mines of British Columbia).

All of the above samples were taken in the split return airways and main return airways of operative mines, and do not include any 'face' samples.

AN INVESTIGATION OF CERTAIN CANADIAN PLATINUM AND MANGANESE RESOURCES.*

By G. C. Mackenzie

(Annual Meeting, Montreal, March, 1919)

Prior to the war, the world's supply of platinum was derived almost entirely from the Russian Urals; but when hostilities commenced in the fall of 1914 the Russian production was reduced almost one-third, due principally to the conscription of miners for the Russian army. This state of affairs was further aggravated by the fact that a very large quantity of platinum was required by the munition industries of England, France and the United States, in the manufacture of sulphuric acid, and also for the ignition apparatus of all types of internal combustion engines.

The U. S. of Colombia, in South America, is second only to Russia as an important source of platinum, producing in 1913, 15,000 ounces as against Russia's 250,000 ounces; but in 1916 Columbia produced 25,000 ounces, the Russian output falling to 63,900 ounces that year.

In 1906 platinum was worth from $20 to $38 per troy ounce; in 1914 its value increased to an average of $45 per ounce. At the end of 1915 the price had again advanced to $85 per ounce, and by December, 1916, had reached a figure of over $100 per ounce. In the spring of 1918 the United States Government made an official fixed price of $105 per ounce of refined platinum and adopted stringent regulations governing its purchase and exportation. The British Government followed suit in the fall of 1918 with the notification that they were prepared to pay the official American price for Canadian platinum.

The whole amount of platinum so far produced in the world to date is estimated by Dr. Geo. F. Kunz at 4,000,000 ounces, a quarter of which is assumed to be in the United States, with the addition of about 400,000 ounces of associated platinum metals.

*By permission of Canadian Munition Resources Commission.

He distributes platinum in the various industries as follows:—

	Oz.
Catalyzing	400,000
Dental purposes	1,000,000
Chemical apparatus, etc	1,000,000
Electrical devices	500,000
Jewellery	500,000

Kunz estimates also that the following amounts used for catalyzing purposes are distributed in the different countries about as follows:

	Oz.
United States	200,000
England	100,000
Germany	70,000
France	30,000
Total	400,000

The following table of the world's production is taken from Dr. Kunz's article in the Mineral Industry, Vol. XXV:

World's Production of New Platinum in 1913-1919, by Countries

(In troy ounces.)

Country.	1913	1914	1915	1916
Russia, crude	(a)250,000	(a)241,200	(a)124,000	(a) 63,900
Canada, crude (b)	(a)50	(a)30	(a)100	(a)60
New South Wales and Tasmania, crude (c)	1,275	(a)1,248	303	222
Colombia, crude	(a)15,000	(a)17,500	18,000	25,000
United States, domestic crude	483	570	742	750
United States, refined from foreign and domestic matte and bullion (d)	(d)1,100	2,905	5,753	2,256
Borneo and Sumatra and other crude (e)	200	(f)	(f)	(f)
Total	268,108	263,453	148,898	92,488

(a) Estimated. (b) In addition to platinum contained in matte and bullion refined in the United States. (c) Chiefly iridosmine. (d) Does not include refined platinum from domestic crude. (e) Includes small production in Madagascar. (f) No basis for estimate.

As a producer of this metal Canada has, up the present, been of very minor importance. A few hundred ounces are recovered annually from the refining of Sudbury copper-nickel matte by the International Nickel Company in the United States, and probably a somewhat larger amount is produced by the Mond Nickel Company at their refinery in England. In this connection it is interesting to note that the Mond Nickel Company are reported to be making a better recovery of platinum metals by their process of refining than the International Nickel Company have so far accomplished at their New Jersey works.

The report of the Royal Ontario Nickel Commission states that in 1916 the matte produced by the Canadian Copper Company was estimated to contain 5,640 ounces of platinum and 8,460 ounces of palladium, and that the recovery of these metals by the International Nickel Company in that year amounted to 1,093 ounces of platinum and palladium together with 257 ounces of other metals of the platinum group. Recent research investigations conducted by the International Nickel Company have shown that it is possible to improve greatly their recovery of the platinum group metals, and it is probable that these improved methods will be practised in the near future. The Mond Nickel Company did not furnish figures of platinum recoveries to the Royal Ontario Nickel Commission, but from assays made by the Commission it would appear that the Mond Nickel Company's matte contained more of the platinum group metals than the matte of the Canadian Copper Company.

The British America Nickel Corporation will employ the Hybinette process of electrolytic refining, which it is expected will make a more or less complete recovery of the precious metals in the matte.

Should the International Nickel Company succeed in recovering a high proportion of the precious metals, it is well within the range of possibility that the total production of platinum-group metals by the three nickel companies will exceed 10,000 ounces yearly.

Some years ago a considerable quantity of native platinum was produced from the Tulameen district in British Columbia.

There are no data of the amount produced previous to 1885, but since that date the platinum recovered has been estimated by Camsell at 10,000 to 20,000 ounces,[1] and at one time this district was the principal producer of platinum in North America.

In view of the serious shortage in the world's supply of platinum, and more especially because of its importance as a war metal, the Imperial Munitions Board, in June, 1918, requested the Munition Resources Commission to undertake an examination of certain platinum occurrences in Alberta and British Columbia.

One of the first properties to be examined was at Fort Saskatchewan, Alberta, on the Saskatchewan river. The

Empire Hand Drill in operation at Fort Saskatchewan, Alberta.

owners of this property having applied to the Imperial Munitions Board for examination of the ground, and subsequent financial assistance, if sufficient platinum were discovered, the Commission was asked to undertake a systematic examination

[1]Memoir No. 26. Geology and Mineral Deposits, Tulameen District, B.C., G.S.C., 1913.

of the property, and to report thereon at the earliest possible moment.

Dr. W. L. Uglow, of the Commission staff, was sent to Fort Saskatchewan early in June, and made a preliminary report to the effect that both gold and platinum were found to occur, although it was difficult to estimate the value of the ground by sampling methods employed in the preliminary examination. It was then decided to survey and drill the property in an approved manner in order to demonstrate beyond any uncertainty the possibility of platinum production, and an Empire drill was placed at Dr. Uglow's disposal for this purpose. Pending the arrival of the drilling equipment at Fort Saskatchewan, Dr. Uglow was instructed to make a quick trip up the Peace river for the purpose of investigating certain alleged platinum discoveries in the vicinity of the junction of the Finlay and Parsnip rivers with the Peace river. His report on the possibility of securing platinum in the Peace River district was not optimistic, and he returned to Fort Saskatchewan and commenced the drilling of the latter property early in the month of July.

Drilling was continued at Fort Saskatchewan until about the middle of August, during which time 22 holes were put down with the Empire drill; of these, 18 were sunk to a bed-rock, which was a clay-shale. The Fort Saskatchewan work may be briefly summarized as follows:

The gold and platinum occur in the form of very small flat flakes or scales rather larger than the fiftieth of an inch in their largest dimensions, and therefore their recovery by dredging operations would be very difficult. The gravel which carries the precious metal has an average thickness of about 11 feet, and covering a very large proportion of this gravel is a mantle of fine sand silt with an average thickness of 16½ feet. The flakes of the precious metals were found to lie chiefly in the upper four or five feet of the gravel, and therefore their recovery would require the entire removal of the overlying mantle of silt, which itself is almost quite barren. The samples, with one or two exceptions, were found to contain less than 10 cents in

gold and platinum per cubic yard of gravel, and while there are smaller and shallow stretches of the gravel on the river bars which yield values from 12 to 58 cents per cubic yard, the property as a whole was not considered valuable for large scale dredging operations.

Meanwhile early in August, the writer, in company with Mr. Charles Camsell of the Geological Survey, made a careful examination of the stream gravels of the Tulameen river, British Columbia, and concluded therefrom that this stream should be prospected by means of core drills to determine its value as dredging ground. The town of Tulameen is situated in the

Tulameen river, British Columbia, at mouth of Slate creek.

Similkameen Mining Division in southwestern British Columbia, and is reached from Vancouver via Ruby Creek Junction and Kettle Valley railway. The Tulameen river is a small mountain tributary of the Similkameen river, forming a junction with the latter stream in the vicinity of the town of Princeton. In the early days the Tulameen was worked energetically for placer gold, and a considerable amount of platinum was also secured in the past, but as the price of this metal at the time

of early mining operations was only from $5 to $10 an ounce. its recovery was not given much attention.

During the preliminary survey of the Tulameen some small scale-washing operations were conducted with the object of securing a rough estimate of the value of the ground. In those tests about 90 cubic yards of gravel were washed, and the small clean-up made therefrom was distinctly encouraging. The gold and platinum were found to occur in approximately the proportions of 60% of the former to 40% of the latter, both metals being in rather small grains and flattened scales, although there was sufficient evidence from the character of these small particles to point to the fact that the metals had not travelled far from the source of their origin.

Both Camsell and Kemp have described the occurrence of platinum in this district exhaustively, and there is no need of further amplification. Both of these investigators determined the fact that platinum originated with the pyroxenite rocks of the district associated with chromite and magnetite. It is interesting to note in this particular that we were shown several small nuggets of platinum encrusted with chromite which the uninitiated might readily mistake for pure chromite or magnetite. When these small encrusted nuggets were immersed in dilute nitric acid for a short time the coating of chromite was dissolved away, leaving the kernel of platinum.

During our investigation in the field, there were no large nuggets of platinum discovered, but we were shown a very fine collection of nuggets, the property of a Mrs. Cook, of Coalmont. The largest of the Cook nuggets was about the size of a large kernel of corn, and the smallest about the size of a grain of wheat. These nuggets have been on exhibition at various times, and as they are a very unique collection they should be acquired for the museum of the Department of Mines in Ottawa.

The upper portion of the Tulameen river lying above the mouth of Slate creek has a more or less canyon-like character, the banks being very steep and precipitous, and this portion of the river is being worked at the present time by prospectors for

the recovery of the precious metals. Some of these prospectors are working the high benches from 50 to 100 feet above the creek bottom; others are attempting to recover the gold and platinum from pot-holes in the river bed; but the sum total of their operations is rather small, and the production of precious metals is almost negligible, making little better than wages for the operators.

Below the mouth of Slate creek, and for three miles down stream to the town of Tulameen, the character of the river is decidedly different. The river valley broadens to an average width of 900 feet and the gravel lies in large bars and low-lying benches at depths that vary from 20 to over 100 feet. It was this area that was considered should be prospected by means of core drills, The total quantity of gravel has been estimated roughly at 15,000,000 cubic yards, most of which consists of heavy, coarse pebbles, with many boulders the size of a football. Occasionally, large boulders the size of an automobile are encountered, but they are by no means numerous, and should not present any serious difficulty in dredging operations.

The Kettle Valley Railway touches the Tulameen river at the town of Tulameen, three and a half miles below Slate creek, and follows the river for a distance of approximately 20 miles down stream to the town of Princeton. The question of transportation is therefore solved. The river bed between the town of Tulameen and Slate creek is not heavily timbered, although there is some quantity of poplar and jack pine with an occasional good-sized spruce, and more rarely fir and red and white pine. The river has a fall of 116 feet between Slate creek and the town of Tulameen, and flows for the major part of this distance in a series of small rapids interspaced with quiet stretches with an average speed of approximately five miles per hour. The stream is not deep—probably the deepest holes at the foot of the numerous small rapids are not greater than 15 feet, whereas the average depth of the river at low water is about 1½ feet. The river, like all mountain streams, is very turbulent in the spring of the year, but this condition should

not seriously affect dredging operations if due precautions are taken.

Drilling with the Empire hand equipment was commenced in the month of September, and after the completion of three holes, the deepest being 62 feet, it was decided to install a power drill of the Keystone type, as the gravels were too heavy and tight to allow of much speed being made with the Empire equipment.

The chief advantage of the Empire hand drill is its mobility. It will take down so that the largest piece to be transported does not weigh more than 250 lb., and providing that the gravels to be examined are not heavy or do not contain too many boulders considerable progress can be made with this equipment. The manufacturers claim that the essential feature of the Empire is the rotation of the casing during the entire drilling operation. A platform is mounted on the top of the casing upon which four abourers stand and alternately lift and drop the drill rods to which are attached the drilling tools. Providing the ground is not very tight and does not consist of heavy gravel, the rotation of the casing by means of horse-power, together with the weight of the equipment and the men on the platform, will sink the casing as drilling proceeds, and the core of sand and gravel accumulated in the inside of the casing is pumped out as fast as it forms.

A power drill of the Keystone type works in a somewhat different manner. The casing is driven into the ground for every foot made, and as a general rule progress is made by alternately driving for one or more feet and then pumping the core accumulated from the previous driving. When exceptionally large boulders are encountered, drilling below the casing is resorted to and is generally permissible. The Keystone casing is larger and heavier than the Empire, and is driven by means of two steel driving-blocks bolted to the drilling stem, the total weight of which is approximately 800 pounds. In driving, some fifty or sixty blows are struck per minute, with a fall of approximately fourteen inches, and it is an exceptionally large

boulder that cannot be drilled through, broken up or pushed to one side by this heavy and continuous pounding.

When starting with the Empire drill it was quickly demonstrated that the ordinary Empire method of working would not make progress in heavy gravel, and it was therefore decided to erect a tripod over the drill platform and with an ordinary pile driver trip employ a 500-pound driving block of fir in order to drive the casing in the same manner as a Keystone casing is driven. With this equipment, and using a horse to lift the driving block, from two to four blows were struck per minute; considerably better progress was made than by allowing the casing to sink simply by rotation. Notwithstanding this additional equipment the Empire could not keep pace with the Keystone, and the power drill was eventually used exclusively.

Drilling was continued until the second of December, when a heavy fall of snow held up operations, and as no provision had been made to continue during the winter months, the work was stopped and the outfit stored in Vancouver.

From the comparatively small amount of work accomplished it is difficult to arrive at definite conclusions regarding the value of the Tulameen gravels, but it can be stated that results, incomplete as they are, warrant further investigation. Altogether eleven holes were put down, the deepest being 76 ft. 6 in., and the shallowest 11 ft., with a total of 516 ft. drilled. Six holes were put down to bed-rock, the others being stopped at depths at which the values did not warrant further drilling. Bed-rock was found to consist of a rather hard green quartz-schist, which on panning yielded no black sand, but abundance of fresh iron pyrites. Both gold and platinum were found to occur in small scales and pellets, with an occasional colour of gold of approximately one-half milligramme weight. Platinum in the ore samples could not be distinguished from drill steel cuttings, and therefore no log could be made of its occurrence during drilling operations. Gold colours, however, were logged in the customary manner.

Core samples consisting of the total amount of black sand from each hole were forwarded to the Dominion Assay Office,

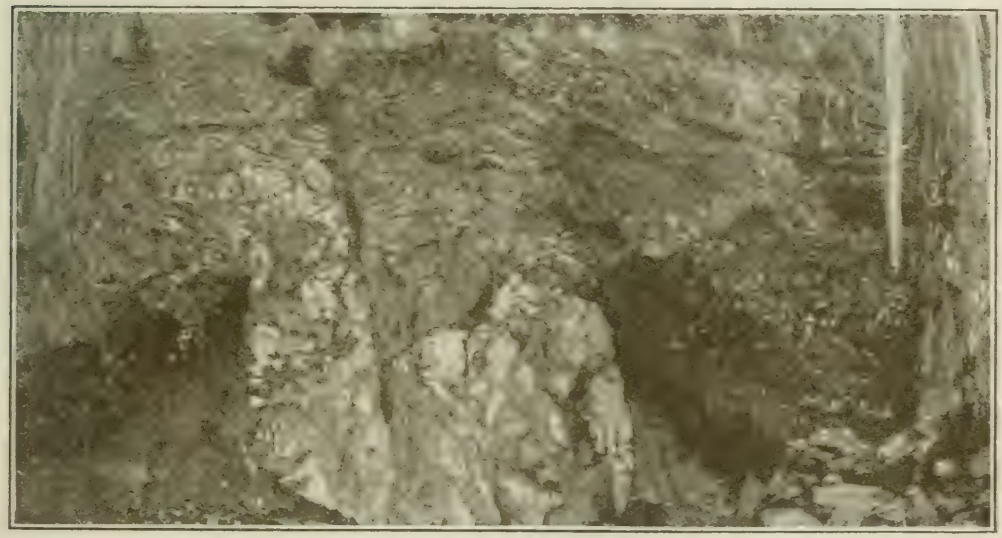
in Vancouver, and in every case the total amount of sample was melted down for assay. This entailed a great deal of work, but was considered necessary because of the difficulty in accurately cutting down to assay-ton samples. No attempt was made to amalgamate gold in the field, because in the recovery of both gold and platinum by large scale operations ordinary methods of amalgamation would not apply.

In addition to the Tulameen work the Commission engaged Mr. Wm. Thomlinson, of New Denver, to undertake the sampling of a large number of specimens from many localities in southern British Columbia where platinum had been reported or was supposed to occur. An alleged occurrence of platinum and gold on Potato creek, Jervis inlet, a short distance north of Vancouver, was examined and reported upon.

A detailed report of all platinum work completed, including drill logs and surveys, will be published by the Commission early in the summer of this year.

MANGANESE

In the month of August last, the writer, at the request of the Canadian War Trade Board, undertook an examination of a new discovery of manganese ore situated near Lake Cowichan



Cowichan Manganese Deposits—view of outcrop on Hill 60 claim.

at the summit of the divide between Chemainus and Cowichan rivers, on Vancouver island.

At the time of the first visit the small amount of stripping accomplished had disclosed the outcrop of a secondary deposit of manganese oxide for a distance of approximately 100 feet, striking 10° south of west, and dipping 70° towards the south.

The deposit lies near the contact of the Sicker series and the Cowichan group, described by C. H. Clapp, in map 17A of South Vancouver island, published by the Geological Survey. The orebody appears to be associated with the quartzite rocks of the Sicker series and consists of manganite and possibly some psilomelane which has undoubtedly been derived from the alteration of rhodonite, the silicate of manganese, which is strongly in evidence on both sides of the orebody. Samples taken across the widest portion of the outcrop indicated approximately 12 feet of ore with a metallic manganese content of better than 50% and with less than 15% of silica. Phosphorus was found to be present in amounts generally less than .075%.

The report to the War Trade Board was to the effect that the deposit consisted of a promising prospect of merchantable metallurgical ore, and that the owners were prepared to develop their property under certain guarantees providing for the marketing of the ore produced. The War Trade Board, after some considerable delay in giving consideration to the proposal, eventually declined to furnish the required guarantees, and no production of ore has taken place to date.

A second inspection of this property was made on the 11th November, and as considerably more stripping had been accomplished at this later date a much better opportunity was given of securing representative samples, which on analyses proved to parallel very closely the results from the first set of samples obtained in August.

Unfortunately, the owners contented themselves with merely stripping the surface, and, although they have disclosed a very attractive outcrop of high-grade metallurgical ore, they had not during 1918 accomplished any cross-cutting or sinking

to prove the quality of the ore at depth. This, of course, is to be regretted, as in all secondary deposits of this nature, particularly of manganese, the deciding factor as regards the value of the deposit is the extent to which oxidation of the original mineral has taken place. That the owners realize the importance of this is indicated by the fact that they are now engaged in removing portions of the outcrop to prove the quality of the ore for at least 10 feet below the surface.

If the Cowichan deposits are proved to contain a large tonnage of metallurgical ore, such discovery would be of considerable importance to the iron and steel interests of this country. At the present time, Canadian iron and steel works are using rather over 1,000 tons monthly of ferro-manganese, all of which is imported either from England or the United States, and therefore if a domestic supply of manganese ore can be assured its utilization should be carefully investigated. The situation of the deposits with respect to the market in eastern Canada is unfortunate, and it is a matter of doubt whether it would be advisable to manufacture ferro-manganese on the coast, or transport the ore by boat to Atlantic ports via the Panama canal. The prospect for the manufacture of ferro-manganese on the coast possesses several attractive features and one outstanding problem, which is the cost of electric power. According to figures given to the writer and also quoted by Dr. Stansfield in his report on the iron smelting possibilities in British Columbia, electric power is quoted at a considerably higher figure than would admit of profitable electric smelting, even in the case of ferro-manganese.

The Commission intends to publish very shortly all information at its disposal on the Cowichan manganese deposits, and the possibilities of manufacturing therefrom in Canada high-grade ferro-manganese.

DISCUSSION

MR. J. B. TYRRELL: Mr. Mackenzie has given us an interesting account of his investigations into both the occurrence and the value of gold and platinum in the alluvial gravels and

sands of the Tulameen and Saskatchewan rivers in British Columbia and Alberta, respectively.

These two streams represent different types of valley formation, and consequently the alluvial deposits formed by them, and in which grains of gold or platinum may be present, are arranged in different ways.

The Tulameen river above the mouth of Slate creek would seem from his description to flow in a V-shaped valley with a narrow bottom in which there was comparatively little accumulation of alluvial wash, except such as was dropped behind rocky dams. Apparently the bottom of the valley has not been widened to any extent by meandering of the stream. If, therefore, a paystreak carrying heavy metals such as gold and platinum exists in this portion of the valley it occurs in the point of the 'V,' and its location is in consequence a comparatively simple matter.

Below the mouth of Slate creek the stream would appear to have a much lower grade. It is no longer deepening its valley, but is depositing gravel, in some cases to a depth of 72 feet at least. The valley bottom is now 900 feet wide with the river meandering from side to side in it. It would be interesting to know whether we have here a definite filling of a V-shaped valley with sand and gravel, in which case the paystreak would still continue to run along the bottom of the 'V,' or whether the whole rock bottom of the valley has been widened by the meandering of the stream, in which case the paystreak, if it exists, would mark the original position of the bottom of the old V-shaped valley, even though it now lies on a comparatively level floor. We are told that a paystreak has been definitely discovered, though it has not been traced for any great distance. In that case it would be wise for those in charge of future explorations to have a careful physiographic survey of the valley made in order to determine its exact method of formation and growth, and the consequent position of the remainder of the paystreak under the alluvial gravels. Such an investigation would not be for the purpose of satisfying mere academic curiosity, but would be a definite application of known

principles on the formation of paystreaks to results of economic and financial value.

The Saskatchewan river in the vicinity of Edmonton and Fort Saskatchewan has a different character from the Tulameen, and has excavated a different style of valley. The rocks through and over which it flows are soft and easily eroded, and form no hard barriers to break the regular and even flow of the water. Consequently, although the stream slowly cut its way through the soft rock and deepened its valley, it also, at the same time, meandered and widened it, depositing beds of sand and silt in the bends. In other words, it cut its valley both downwards and laterally by a constant serpentine or whiplash movement. Such a mode of formation is different from the constant downward cutting of a V-shaped gorge in which water flows in a comparatively narrow channel, and into the bottom of which any heavy metals would settle. The serpentine movement and constant change of position of a stream like the Saskatchewan does not permit of the flow of water for any great length of time in one definite channel, and consequently heavy material carried by it does not continue to drop along a narrow course, as in a gorge, but is distributed by the windings of the river, and the constant changes in the position of its bends, across the whole width of the bottom of the valley. In such a case, therefore, no regular well-defined paystreak was formed, and the only concentration of heavy material that might be looked for would be in association with coarse gravel on the upper side of the bends, and not necessarily on bedrock.

Mr. Mackenzie's investigations furnish interesting corroboration of the above principles in that he finds "the precious metals to lie chiefly in the upper 4 or 5 feet of the gravel" on the banks of the Saskatchewan, and not on bedrock.

SOME ECONOMIC ASPECTS OF THE FALCON LAKE DISTRICT, MANITOBA

By J. S. DeLury

The Falcon Lake district of Manitoba is adjacent to the Lake of the Woods area of Ontario, and it received considerable attention from gold prospectors during the boom period in the history of that area. Since that time there has been some desultory prospecting in the country to the north of Falcon lake and fitful attempts at development work have been made, particularly in the vicinity of Star and West Hawk lakes. During this time many interesting occurrences of various types of ore have been brought to light and in the past two years added interest has been taken in the district on account of the finding of tungsten and molybdenum ores. While none of these deposits has so far proved to be of commercial importance, they are of interest in the great variety of minerals they hold, in the associations and origin of the minerals, and in the bearing their study has on the interpretation of the origin of the gold veins found in the Lake of the Woods area. To bring out these economic features is the special object of this paper, so that it will be necessary to write only briefly on the general geology of the district and to refer the reader to papers[1] that have already been published on this and adjacent areas.

The Falcon Lake country is similar, both geologically and superficially, to that around the Lake of the Woods as described by

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[1]Lake of the Woods Region, by A. C. Lawson; *Geological Survey, Annual Report*, 1885, Part CC.

Gold Fields of Lake of the Woods, by A. L. Parsons; *Ontario Bureau of Mines, Annual Report*, Vol. XX, Part 1, p. 158 and Vol. XXI, Part 1, p. 169.

Star Lake District, by R. C. Wallace; *Manitoba Public Utilities Commission Report*, 1916.

Molybdenite at Falcon Lake, by J. S. DeLury; *Canadian Mining Journal*, Vol. XXXVIII, No. 23, p. 460.

Tungsten Ore Deposits near Falcon Lake, by J. S. DeLury; *Canadian Mining Journal*, Vol. XXXIX, No. 11, p. 186.

Molybdenite near Falcon Lake, by E. L. Bruce; *Geological Survey, Summary Report*, 1917, Part D, p. 22.

Star Lake Area, by J. R. Marshall; *Geological Survey, Summary Report*, 1917, Part D, p. 21.

Lawson, Parsons and others. The area was actually included in Lawson's map, but coloured as being occupied by Laurentian gneiss. In his map of the country near the Ontario-Manitoba boundary, Parsons indicates the presence of an important belt of schists which he suggests is a continuation of a similar belt seen on Woodchuck bay in Lake of the Woods. Later the writer extended the map to include those parts of Manitoba which contain the recently discovered occurrences of molybdenite and scheelite.

Lawson groups the formations of the Lake of the Woods area in the following manner:

KEEWATIN.
- Hydromica schists, etc.
- Clay slate, etc.
- Agglomerates.
- Hornblende schists and altered traps, etc.

LAURENTIAN.

LATER GRANITES.

LATER DIORITES.

Representatives of most of these formations are found in the Falcon Lake district. The belt of schists corresponds to the Keewatin, and in it are found many of Lawson's types. Granites occupy the areas on either side of the belt; they appear to be of two distinct types and to belong to two different periods of formation. The older granite is typically gneissic in structure and probably corresponds to Lawson's Laurentian; the younger one, which is clearly intrusive into the other, probably corresponds to his later granite. The Laurentian is apparently confined to the northern parts of the area under discussion, and little reference to it is needed in the discussion; it is intrusive into the schists and is intruded by a younger granite.

The later granite is found on both sides of the schists and is plainly intrusive into them. It appears to be part of a huge batholithic intrusion which is the prevailing rock over a great area of Manitoba, being found far to the west, north at least as far as the Winnipeg river, and northwest in many parts

of the Lake Winnipeg country. In many places near the contact of this granite with the schists are found felsitic and porphyritic phases formed from the same magma. There are many varieties of the granite, depending on the size of the mineral grains and on the relative abundance of the constituent minerals, but typically it is a coarse-grained rock showing large idiomorphic feldspar crystals embedded in a finer-grained matrix of quartz, feldspar and biotite. It generally shows a distinct reddish colouration.

A description of the schists which occupy a belt in this area will show clearly that they correspond to one of Lawson's Keewatin belts. The most prominent member in the Falcon Lake belt is a hornblende schist which was apparently largely derived from basic ellipsoidal lavas. Conglomerates occupy one important area lying to the west of Star lake; the boulders and pebbles contained by them vary greatly in size and contain, besides abundant finely and coarsely grained basic igneous rock material, considerable quartz and quartzite; hence they must be regarded as true conglomerates and not the same as the agglomerates described by Lawson. Banded sediments, garnetiferous sericite schists, many other varieties of schist, some of them derived from sediments as indicated by the presence of graphite, others from different types of acid and basic felsitic igneous rocks, and also some fairly massive basalts, diabases and diorites, all occur in usually small and scattered areas or bands and make up the remainder of the belt.

Lying within the belt of schists and occupying a considerable area between Star and Falcon lakes is a body of very coarsely grained syenite. It is intrusive into the surrounding Keewatin rocks and is older or of about the same age as the later granite. It is of interest in that it may have had something to do with the mineralization of adjacent parts of the district.

The belt of schists strikes northeasterly in the southwestern part of the area. In the vicinity of West Hawk lake it turns easterly and strikes towards the Lake of the Woods. A section across the belt in the eastern part of the field shows Laurentian gneiss in contact with the schists; it has many fine-grained

phases and makes a wide *lit par lit* contact zone. A wide band of sedimentary and igneous schists lies between this gneiss and the later granite which appears to the south in the vicinity of High and Falcon lakes. Along this contact are narrow to wide bands of felsites and porphyries which doubtless came from the same magma that produced the granite. Sections across the western part of the belt show the schists lying between intruding masses of the later granite; typically there is a rather sharp contact between coarse-grained granite and schist; commonly there is an inter-fingering contact zone with the occurrence of some fine-grained phases of the granite; and more rarely are to be seen some of the last phases of the cooling granite magma in the form of pegmatite and aplite dykes.

The important geological event in connection with the formation of the orebodies of the district was without much doubt the intrusion of the later granite. It appears along both sides of the belt of schists and is plainly intrusive into them. This granite is similar to a granite described by Lawson as occurring near the Lake of the Woods gold veins; that they are identical is strongly indicated by a comparison of the associated ores as found in the two localities.

Throughout the area occupied by the schists there have been found a great variety of ore deposits, many of which, though small, have attracted attention. During the time of the Lake of the Woods boom many small veins showing good values in gold were located. Later on some work was done on large and continuous zones of schist which are strongly filled and impregnated by several kinds of sulphides. They occur mainly in the vicinity of Star and West Hawk lakes. In a large number of veins in the belt are found such minerals as gold, bismuth, galena, sphalerite, chalcopyrite, pyrite, pyrrhotite, arsenopyrite, bismuthinite, molybdenite and magnetite, associated with a great number of high-temperature silicates and other gangue minerals in a variety of associations in different deposits. During the past two years interest has mainly settled on the recently discovered occurrences of molybdenite and scheelite. The source of some of these deposits is so evident and there are so

many types apparently grading into each other that it is considered worth while to present some ideas, gained principally from a brief investigation in the field, in regard to the origin of many of the deposits and their relations to each other and to the parent granite, leading up to the establishment of the parent rock of the Lake of the Woods gold veins and other economic aspects of that field. To bring out these features it will be necessary to indicate briefly the nature of the various ores of the Falcon Lake district; in doing this the deposits will be considered in the order of the directness of their association with the later granite, those having the most direct and undoubted connection will be mentioned first and will be followed by those having an uncertain origin.

Pegmatite Dykes.—These are usually found within a few hundred feet of the later granite; they outcrop as more or less continuous bands from two to ten or more feet wide and parallel to the layers of schist, which in most parts of the district are nearly vertical and parallel to the contacts with the granite. They are, in most of their features, the typical pegmatites formed from granite magmas. In some parts the pegmatite is very coarsely grained with individual crystals a foot or more in diameter; in other parts it is finer and contains considerable graphic granite. Besides the usual feldspar, quartz, and mica, other minerals such as beryl and garnet occur in small amount. Molybdenite is the only prominent metallic mineral in the dykes. It occurs in crystals, as a rule; these are typically large, an inch or more thick, though smaller ones are seen. Exceptionally the molybdenite occurs as a massive fine-grained variety. In places the coarser individuals are aggregated into quite large masses, some of them weighing in the neighbourhood of twenty pounds. The molybdenite crystals are primary constituents of the pegmatites and are idiomorphic at least with respect to much of the quartz.

Aplite Dykes.—A few narrow dykes of aplite up to two or three feet in width were seen in the district. They are made up principally of quartz, feldspar and a little mica which are in small equidimensional grains, and they carry molybdenite in

grains which are distributed unevenly through the rock, some parts having none.

Pegmatitic Quartz Veins.—On two claims, the IXL and the Hall, occur veins which consist mainly of quartz but also show pegmatitic materials distributed principally in bands along the walls. They are best regarded as transition types between the true pegmatites and quartz veins. They are of great interest in the nature of the metallic minerals they carry. The most prominent of these is molybdenite. Bismuthinite occurs in close association with molybdenite in one of the veins and a little native bismuth is embedded in the quartz of the other vein. Small masses of arsenopyrite and grains of chalcopyrite were also noticed. Gold assays running about ten dollars to the ton were obtained from one of these veins. One specimen showed free gold embedded in bismuthinite. In their relations to the including schists, these veins differ somewhat from the pegmatite and aplite dykes. The latter are parallel to the schistose structures of the rock and the former cut across them more or less. One of the veins is about fifty feet from the contact with the granite; the other is about half a mile. Both of them are quite irregular in width.

Molybdenite-bearing Quartz Veins.—In the vicinity of High lake and the east end of Falcon lake, near the contact of the schists and granite, are some wide bands of felsitic and porphyritic phases of the granite magma. In these, and in the schists, irregular masses, narrow veins and groups of stringers of quartz are found occupying fissure and shear zones. The quartz is fine grained, and in many places carries very finely divided molybdenite in quantities varying between traces and five or more per cent. Small grains of pyrite are associated with the molybdenite, and the average of several samples indicates the presence of gold and silver values amounting to one dollar per ton.

Scheelite-bearing Deposits.—These were probably formed during a very late stage in the consolidation of the magma which produced the later granite, and later than all or most of the

previously described types of ore. The scheelite and associated minerals are found along zones of movement, indicated by the presence of fault-breccias, contorted schists, and slickensided surfaces along definite walls. Many high-temperature silicates, such as feldspar, epidote, vesuvianite, amphibole, and garnet, with scheelite, quartz and calcite, and small amounts of ilmenite, sphene, molybdenite and an unidentified iron-bearing phosphate, were formed by the high-temperature solutions from the magma as a result of the filling of irregular cracks and openings and an interaction with the surrounding schists. Some pyrrhotite and a few grains of chalcopyrite are also present in the ore.

Sulphide Zones in Schists.—In the vicinity of Star and West Hawk lakes are many wide and continuous bands of schist which have been extensively impregnated by various kinds of sulphides. These zones are striking with the formation; the dip is also that of the schists. They were developed along zones which appear to have suffered the last serious disturbances of the district. The prominent minerals in these bodies are pyrrhotite and pyrite. Sphalerite was seen in several places and is probably more abundant than would be indicated by an examination of hand specimens. Rock stained by malachite indicates the presence of some copper. It is probable that galena is also present as lead appears to have been reduced by rather crude methods from some of the ore. Similar methods have indicated the presence of tin; if this metal is present, it is doubtless in the form of stanniferous pyrites. The sulphides are said to carry gold and silver values, but the writer has no positive information in regard to this. Nickel in small amount has also been reported from samples rich in pyrrhotite.

There is no positive information in regard to the source of the material found in these sulphide-bearing zones; however, there are some features which point to the later granite as the possible source. In one place the sulphides occupy spaces in a fractured pegmatite dyke which is apparently one of the phases of the later granite, indicating that the fracturing which led up to the deposition of the sulphides was one of the latest disturbances. Associated with the sulphide bodies are some of

the high-temperature minerals found with the scheelite. Scheelite was found closely connected with the sulphides in at least one locality.

Other Ores.—The ore from the Penniac mine in the vicinity of Star lake has been described by Wallace as a high-temperature deposit consisting of fine-grained quartz carrying pyrrhotite, arsenopyrite and free gold, together with small grains of feldspar and garnet. Other ores occur in the vicinity of Star lake. They occupy fissures and shear zones in, and near, the body of coarse-grained syenite which was mentioned above as occurring within the belt of schists. Among the sulphides carried in these deposits were noticed arsenopyrite, sphalerite and galena. Some of them have free gold, and several assay returns from samples taken by Marshall and others indicate the presence of platinum in small amount. The close association of these ores with the syenite indicates a possible origin from that rock; on the other hand, they may have been derived from the later granite. The syenite is cut in places by materials which apparently came from the granite. Many of the minerals found in the ores associated with the syenite are to be found also in deposits which have undoubtedly come from the later granite.

Ores in the Lake of the Woods Area.—The occurrences of the Lake of the Woods gold veins as indicated by Lawson and Parsons are close to outcrops of a later granite which, judging from their description, is probably the same as the later granite which outcrops so abundantly in the Falcon Lake district. The mineral associations in some of the gold veins give further indication that the granites in the two areas are identical. The Mikado ore, made up of quartz carrying pyrite, chalcopyrite, bismuthinite, molybdenite and free gold, is very similar to that found in the pegmatitic quartz veins near Falcon lake. The Sultana ore carries free gold, molybdenite and other sulphides. Molybdenite appears to be very commonly distributed throughout the Lake of the Woods area and there are other types of ore showing associations of metallic minerals similar to those men-

tioned as occurring in the vicinity of Star and West Hawk lakes.

Conclusions.—1. Some of the gold, as well as the molybdenum and tungsten minerals, of the Falcon Lake district has been derived from the later granite. The similarity of some of these ores in their associations of minerals to the gold veins of the Lake of the Woods area indicates that these latter veins were also derived directly from the same granite.

2. The Lake of the Woods area is probable ground for the finding of tungsten ores, and of molybdenite, of which there are now so many known occurrences.

3. The bands of schist impregnated with sulphides do not correspond to an 'Iron-Formation' as that name is understood; the sulphides are probably direct products of igneous intrusion.

4. As is true for so many parts of the pre-Cambrian, there is great necessity for work to be done in attempts to correlate and separate the granite masses found in these areas.

MINING DEVELOPMENT IN NORTHERN MANITOBA

By R. C. Wallace

The area commonly known as Northern Manitoba embraces all the territory north of township 44 and south of Lat. 60°, within the province of Manitoba. Of the total area within this territory (178,000 sq. miles) only a relatively small part has been surveyed. The early explorations date from 1612, when Sir Thomas Button reached the mouth of the Nelson river, and were confined to investigations of the possibilities of a route to the South Seas through Hudson bay. From 1670 onwards, trading posts were established under the Hudson's Bay Company, and the explorations had the sole aim of opening connections with the Indians for the fur trade. It may be that Henry Kelsey travelled through a considerable part of this territory on his journeys in 1690, about which much vagueness still exists. Immediately subsequent to the time of LaVerandrye, the French traders had attained a foothold in the Saskatchewan valley, but we are indebted to LaVerandrye's sons for actual descriptions of the Saskatchewan territory. This was in 1741. Later, through Samuel Hearne, the Hudson Bay's Company established trading posts on the Saskatchewan river, and from that time onwards traders from the rival companies doubtless journeyed through much of the territory north of the Saskatchewan river. The first careful mapping was done by David Thompson in the latter years of the 18th century and early years of the 19th century, covering the districts immediately north and northeast of Cumberland House.

While geological notes were made and rocks collected by Dr. Edwards in 1912 and by Sir John Franklin and Dr. Richardson in their two overland journeys to the Arctic, and while a fairly full description of the Saskatchewan territory was given by the Hind Expedition, detailed mapping has been carried on practically entirely under the Geological Survey of Canada.

The explorations of Bell, Cochrane, Low, Tyrrell, Dowling, and McInnes are well known, and have been fully summarized by McInnes in the memoir on the basins of Nelson and Churchill rivers. Since mining developments have become important, five seasons have been spent by Bruce and two by Alcock in the district north of The Pas; and to them is due full acknowledgment for the information available as to the detailed geology of the belt in Northern Manitoba, which has attracted attention among mining men during the past few years.

The territory in question is flanked on the northeast and southwest by Palæozoic sediments. In the central area the pre-Cambrian, which probably represents the eroded arch of the great anticline, is exposed. In this there are several isolated areas, which were classified on the old maps as the Huronian. Of such areas only one has been mapped in detail, i.e., the belt extending from Amisk lake, in Saskatchewan, eastwards to Wekusko lake, directly north of mile 82 on the Hudson Bay Railway.

This area wil be designated The Pas Mineral Belt. The geological sequence as determined by Bruce is: *First*—A series of basic volcanics overlaid by sedimentary and igneous gneisses. *Second*—Quartz porphyry intrusives. *Third*—A lower and upper series of sedimentaries, consisting mainly of conglomerates and quartzites. *Fourth*—Granite intrusives, characterized by a fresh unweathered aspect. The sequence bears very striking similarity to that in many other districts, but on account of the isolated nature of the belt, no attempt was made to correlate with the sequence shown elsewhere. At the other area of the so-called Huronian, which includes in Northern Manitoba exposures on File lake on the Burntwood river, Cross and Pipestone lakes and the Echimamish river on the Nelson, Oxford and Knee lakes on the Hayes river, and at God's lake and God's river and Island lake in the eastern part of the territory, no definite sequence has been suggested, as detailed work is still lacking. It is noteworthy that conglomerates and other sedimentaries have been found in practically all areas in which exploratory work has been done.

ECONOMIC GEOLOGY

Three types of ore deposits have been located in the areas in question. *First*—Sulphide bodies, in which pyrite and pyrrhotite are the main constituents, but which, in places, contain sufficient percentages of copper and zinc sulphides, with low values in gold and silver, to make the deposits valuable under present transportation facilities. *Second*—Gold deposits, occurring in quartz veins or in wide shear zones infilled with quartz. The mineralization is considerable, arsenopyrite usually occurring with pyrite and chalcopyrite in variable amounts. Tourmaline frequently occurs in the quartz and in the hanging wall. A telluride has been identified in one district (Wekusko lake). *Third*—Magnetite in a typical iron formation. Native silver has been reported on several occasions by prospectors from districts north of the Churchill river, and between the Churchill and Burntwood rivers, but such occurrences have not been confirmed.

At the present moment the sulphide bodies are the most important of the three types. Their known occurrences are confined to the western part of The Pas Mineral Belt, from Flinflon lake on the Manitoba-Saskatchewan boundary to Island lake on the Grass River system. As the eastern part of this belt is overlaid with lake clays, and as the sulphide bodies have suffered considerable disintegration and are consequently found occupying the valleys where the overburden is at a maximum, very careful prospecting will be necessary before a clear estimate of the value of such bodies can be obtained. As far east as Wintering lake, indications of sulphide are found in the exposed rock formations adjacent to the lakes and rivers; but successful prospecting is hardly feasible in this district, where th· overburden is continuous. From the sulphide bodies at the western end of the belt alone has any clear idea been obtained of the relationship to the surrounding formations. The mineralization is in all probability due, as in the case of the quartz veins, to the granite intrusives, acting by replacement in zones which have been shattered through faulting and drag-folding. It would appear that the primary mineralization was in all cases

pyrite and pyrrhotite, while the copper and zinc sulphide have been introduced through subsequent infiltration and replacement. In cases where the copper and zinc ores have not been found to occur in orebodies, these bodies have probably not been subjected to the action of the later solutions. That the structure of the rock has been a factor of greater importance in the replacement than its petrological character is seen most clearly in the Flinflon orebodies, where 'horses' of massive unmineralized rock occur throughout the orebody, which has evidently taken the place of shattered rock of similar petrological character. In no cases have bosses of granite been found immediately adjacent to sulphide bodies of economic value, but small intrusives in the nature of offshoots from the main granite masses occur in the vicinity of such orebodies, and a definite relationship between the two is evident. The sulphide of copper and zinc occur more or less in the centre of the bodies, which grade off into iron sulphide towards the margins. It would appear from microscopic investigations that such sulphides have definitely replaced the iron sulphides that were originally deposited in these zones. In places the concentration of copper sulphide is remarkably high, as in the Mandy orebody, where the lens which is now being worked, occurs in the centre and towards the foot-wall of the body and grades off towards the hanging-wall into a mixture of copper, iron, and zinc sulphides, and finally iron sulphide. In the cases of the Flinflon orebody the values in copper are more uniform throughout the workable orebody, occurring not as an intimate mixture with the other sulphides, but as narrow sheets or veins throughout the body. If, as the evidence seems to indicate, the sulphides, as well as gold-quartz, have been derived from the granite intrusives, it is, reasonable to expect that the lower temperature sulphides will, with depth, grade into the higher temperature quartz-gold-arsenide deposits. The sulphide bodies thus far prospected occur in basic volcanics, and the high degree of seritisation and the presence of calcite indicates that the deposition has been effected through hydrothermal processes rather than by direct differentiation.

The gold-quartz veins show a high degree of similarity

throughout the areas where prospecting has been carried out. They occur normally in the basic volcanics and associated acid phases and exceptionally in sedimentaries involved in the igneous complex. As a rule they follow the strike of the rock, in zones which have been sheared and drag-folded, and, in The Pas Mineral Belt, tourmaline, and throughout the districts arsenopyrite, indicate that at least the major part of the deposition has been effected under high temperature. There seems little reason to doubt that there is a relationship between the later granite intrusives and the veins. To what extent the gold itself has been deposited at the same time and under similar high temperature conditions has not been determined. A somewhat different type of gold deposit has been found in isolated occurrences throughout the area, where wide zones of pegmatite or porphyry have yielded to shearing in planes parallel to the walls, and in these planes quartz carrying gold has been deposited. Some deposits of the latter type may be found to carry sufficient values to permit operation as large low-grade bodies. As a rule the sulphides are subordinate, occurring normally on the walls and the adjacent shear zones in the quartz. Careful investigation has not yet been carried out to determine whether tellurides of gold occur normally in the veins. A telluride has been determined in the Northern Manitoba property at Wekusko lake.

Iron deposits of economic value have not been found. Iron was reported almost a century ago on Knee lake on the Hayes River route. As in the occurrences in the eastern section of the Rice Lake district, and south of Star lake in the older section of the province, this deposit would appear to be a typical banded iron formation, with the iron mainly in the form of magnetite. The percentage of iron and the extent of the bands are not sufficiently great to warrant the expectation that the ore could be operated under present transportation conditions.

MINING OPERATIONS

Before prospecting became general in the Beaver Lake territory in the western extension of The Pas Mineral Belt in Saskatchewan, prospecting had been carried on in isolated

localities on a small scale. Some years previous to the Beaver lake activity in 1913, a map had been prepared by Brunne of the Cranberry Lake district, showing claims staked for copper on Copper and Brunne lakes. A few claims had also been staked on Pipestone lake and the surrounding belt. In 1913 discoveries of gold on Beaver lake in Saskatchewan led to activity in the adjacent territory in Manitoba. In 1914 gold was found on the eastern shore of Wekusko lake. In 1915 the Flinflon ore deposit was discovered and development work was at once commenced. In the fall of 1915 the orebody on Schist lake was discovered, and operations were immediately begun by the Tonopah Mining Company, and a subsidiary (the Mandy Mining Co.) was formed to operate it. Since that time, prospecting has been continuous; on the western half of the belt mainly for sulphide bodies, and on the eastern half mainly for gold. On the north shore of Knee lake, on the Hayes River route, gold was found in 1917, and other discoveries were made in the same district in 1918.

The number of trained prospectors throughout the whole territory has been very small, and their activities have been confined mainly to The Pas Mineral Belt. The claims of the war have reduced their numbers somewhat seriously, and during the past two years the actual prospecting has been limited, and the work has been confined mainly to the development of the few properties which have now reached the producing stage. The actual number of discoveries that may become producers has been remarkably large, when the conditions of the past few years are kept in mind.

The Flinflon Property.—The Flinflon property was discovered in August, 1915, by Thomas Creighton, one of the group of six prospectors, representing the Hammell-Currie-Fasken syndicate. Surface trenching was proceeded with, and in March, 1916, diamond drilling was commenced, and was continued more or less uninterruptedly until June, 1918. On the surface the orebody is at least 2,500 feet in length, part of this being covered by water in the bay of Flinflon lake. A width of 85 feet of sulphides, occurring in two bodies separated by 40 feet of barren

rock, is shown in a trench in the south part of the orebody, while further south an uninterrupted width of 70 feet of sulphides is trenched. It is understood that 'horses' of unmineralized rock occur throughout the orebody, and that the work of diamond drilling, on which, and other developments, some $200,000 has been spent, has resulted in a fairly complete mapping of the whole orebody. Apart from the unmineralized rock, the orebody shows fairly uniform values, the average having been given as somewhat over nine dollars, with normal prices of copper.

The actual extent of ore blocked out by the drills has not been disclosed by the parties officially interested in the property; but there is responsible authority for the statement that the orebody, representing at least between 15,000,000 and 20,000,000 tons, shows average values as above mentioned. The mixture of copper and iron sulphide is so intimate throughout the orebody that concentration will not be possible; hence mining operations will await the advent of the railway to the property and the erection of a smelter at some convenient point. Several important mining companies have been interested in this property, but no transfer has yet been made, and some of the original owners, with some new interests, still own the deposit, which is generally known as the Fasken-Black property.

The Mandy Mine.—When this property was discovered in October, 1915, by Jackson and Reynolds, it was at once taken over by J. E. Spurr, acting for the Tonopah Mining Company. The Mandy Mining Company was formed and, in 1916, $40,000 was spent in preliminary work, and a lens showing 100,000 tons of high grade copper ore was blocked out in the centre and towards the foot-wall of the orebody. While in places the percentage of zinc was fairly high, it was found that parts of this lens give an average of very nearly 20 per cent copper, with low values in zinc and with small amounts of gold and silver. It was decided to operate this property, far removed as it was from ordinary transportation facilities. In December, 1916, H. C. Carlisle, Superintendent for the Mandy Mining

Company, let a contract for the hauling of at least 3,000 tons to the head of navigation 40 miles distant. During the summer of 1917, 3,300 tons were conveyed by barge to The Pas and thence shipped to the smelter at Trail. The total transportation distance is approximately 40 miles by waggon, 130 miles by water and 1,200 miles by rail. This was therefore an unique undertaking in mining transportation. The following are approximate figures and values for shipments to the smelter during the summers of 1917-18:

1917—3,300 tons shipped:

Copper	$261,360	18% @ 22c
Gold	6,600	.10%
Silver	6,600	2½ oz. @ $1.00
	$274,560	

1918—6,000 tons shipped:

Copper	$624,000	20% @ 26c
Gold	12,000	.10%
Silver	15,000	2½ oz. @ $1.00
	$651,000	
Total to date	$925,560	

At the present time almost 15,000 tons are ready for transportation, and 200 teams are at work on the 40-mile stretch between the mines and the head of navigation. It is expected that almost the whole of this ore will be shipped to the smelter during the summer of 1919.

In the first year of operation and until machinery could be transported to the mine the ore was mined from open cut. After the plant was installed a vertical shaft was sunk and the ore has been stoped, first from a drift at the 100-ft. level and latterly from the 200-ft. level. The greater part of the ore of sufficiently high grade to permit shipment by the present method has now been mined to the 200-ft. level, and at the present time a diamond drill is in operation prospecting for similar lenses at greater depth. It is estimated that 200,000

tons of ore averaging 8 to 10 per cent copper, 20 per cent zinc, 0·10 per cent gold, and 2½ oz. silver have been blocked out. The development of this ore must await the establishment of a less expensive system of transportation.

Apart from the sulphide bodies described above, the sulphide discoveries in The Pas Mineral Belt, which have not yet been proved to be of economical value, are of two types. The first consists of pyrite and pyrrhotite lenses similar in origin to the economic deposits, but with low values in copper and gold. Such occur on the south shore of Sandy lake, on the west shore of Copper lake, and elsewhere in smaller amounts. Pyrrhotite is the chief sulphide, fine grained and graphitic in character, and carrying, in a very extensive exposure at Copper lake, low values in nickel. The other type is found on the north shore of the eastern arm of Lake Athapapuskow and eastwards along the north shore of Cranberry lakes. Disseminated crystals of chalcopyrite and bornite, and narrow stringers of the same minerals, occur over wide exposures of massive basic volcanics, which have not been subjected to shearing movements. Sufficient surface work has not yet been carried out on any one of these somewhat extensive exposures to determine whether it will be possible to work any of the properties as low grade copper orebodies when railway transportation shall be available and a customs smelter shall have been erected in the district. It would appear from surface indications that, if the values justify operation, the concentration of the ore will be a relatively simple process.

GOLD MINING

The Rex Mine.—In the summer of 1914 the Kiski and Wekusko gold-quartz claims were staked on the east shore of the Wekusko lake. Prospecting in this area was stimulated by the relatively easy transportation afforded by the Hudson Bay Railway, and many prospectors confined their attention to quartz veins on Wekusko lake, Little Herb lake, and the district westwards to Island lake, Elbow lake, and the Copper Lake country. On the Wekusko lake there was staked the Rex group, Moosehorn group, Dauphin-Elizabeth claims and the Mc-

Cafferty property, on all of which considerable development work has been done, while many other properties in this district and elsewhere show favourable indications from the assessment work which has been performed on them. One property—The Rex—has reached the producing stage. Makeever Bros. have erected a 40-ton Lane mill, with amalgamation plates, and two Deister Overstrom tables, a 55-H.P. engine, two 60-H.P. boilers and a 390 cu. ft. air compressor. The mill was in operation from May 1st to December 1st, 1918, when adverse labour conditions, accentuated by the influenza epidemic, necessitated its closing for the winter. Approximately $27,000 of gold were obtained from the plates during the time of operation, representing the first regular output of gold from any mine in Manitoba. The amount of underground work is relatively small and is confined to stoping from the drift on the 100-ft. level, and it was possible to employ a single shift only to operate the mill. The vein is exposed for 1,700 feet and has an average width in the shaft and drift of probably 4½ feet. The values throughout this width range from $110 to $6, with an average of over $20. Sulphides are unimportant except on the walls. The concentrates from the table are stored for extraction when a cyanide plant shall have been added to the mill equipment. It is planned, upon the resumption of operations in the spring, to pursue much more extensive underground developments, in order that the mill may be operated on a continuous basis.

Makeever Bros. carried on some development work on the Dauphin-Elizabeth claims and later took an option on the Northern Manitoba property, from which a trial shipment of approximately 30 tons had given returns of $81.53 per ton. A vein about a foot and a half in width has been followed to the 100-ft. level, and maintains its width and very high values to that level. Mineralization is somewhat more extensive than on the Rex property, and arsenical pyrites in particular occurs rather plentifully on the hanging-wall and in the adjacent vein quartz. On the original discovery, the Kiski-Wekusko, three veins have been stripped, and a shaft and shallow pits have been sunk. In the summer of 1918, a somewhat spectacular discovery was made on Copper lake, in the district in which a large

pyrrhotite body had previously been found Extraordinarily rich surface samples of gold-quartz were found on this property, but sufficient time has not yet elapsed to ascertain the average tenor of the ore. Gold discoveries somewhat different in character from those already described were made in two widely separated areas during 1917 and 1918. In 1917, H. M. Paull, acting for English capitalists, sent prospectors into the mineral belt on the Hayes River route, which was mapped as Keewatin and Huronian; late in 1917 gold was discovered in a wide belt of sheared porphyry on the north side of Knee lake, and another belt was discovered in 1918. The result of surface channelling would seem to indicate that these properties may admit of operation on a large scale; and undoubtedly prospectors will be attracted into this new field. In 1918, P. Gasse discovered, on the north side of Wekusko lake, a somewhat similar sheared and silicified zone in the granite. This also carries considerable values in gold, and surface indications are very promising.

SUMMARY AND CONCLUSIONS

For the last four years prospecting has been active in the mineral belt north of The Pas, along the Hudson Bay Railway and in some districts north-east of Lake Winnipeg. During the whole period, and especially during the last two years, the number of prospectors has been small. Notwithstanding this fact several ore bodies, which admit of operation under present difficulties of transportation have been discovered; others await the advent of the railway into the mineral belt. From a remarkably rich lens of copper sulphide, ore has been transported to the Trail smelter for two seasons. Other copper sulphide orebodies of low grade, in particular the large deposit at Flinflon lake, can only be developed when a railway shall have been built and a smelter erected at the mine. A reconnaissance survey is at present being made by the Canadian National Railway authorities from The Pas to Cranberry portage, and thence to the Flinflon property—a total distance of approximately 85 miles. A railway along this route would traverse part of the mineral belt and assist in developing several other properties. A situation which demands serious attention

in connection with the initiation of copper smelting in this district is the relatively high cost of fossil fuel. It is desirable that the whole question of electric smelting of copper-sulphide ores on an industrial scale should be studied in the interests of the development of mining in this district. Experimental work has proved fairly conclusively that electric smelting of copper-sulphide is practicable on an industrial scale, and that it is economically preferable to smelting by coke, where coke prices are high and electrical energy readily accessible. Investigations conducted by the Dominion Water Power Branch show that power may be developed at Sturgeon-Weir river 35 miles distant (or on the Churchill river 60 miles distant) from the Flinflon property. There is little reason to doubt that a copper industry of considerable importance will be established in this district, with probably large ore reserves, which it will be necessary to operate on a narrow margin of profit if the value of copper should decline to pre-war prices.

When conditions caused by the war, and adverse to the gold mining industry, are removed, several gold properties will be operated, more particularly in the Wekusko Lake area, which has fairly satisfactory service by the Hudson Bay Railway and government waggon-road. It is expected, however, that prospecting for gold will now be carried on over a much wider field, and that the Pipestone and Cross Lakes areas and the belt on the south of the Hayes river, will, for the first time, receive the serious attention of prospectors. The first and greatest need is undoubtedly the trained prospector. For him the mining field is now an attractive one. The second is sufficient capital —and a large amount will be needed—to establish the copper industry on a secure basis. When both needs shall have been met, Northern Manitoba will become an important factor in the mining industry of Canada.

UNDEVELOPED MINERAL RESOURCES OF THE CLINTON DISTRICT, B.C.[1]

By L. Reinecke

During the summer of 1918 a mineral survey was made for the Geological Survey of Canada of a part of the Clinton and adjacent mining divisions of British Columbia.

The territory covered included the district adjacent to the Pacific Great Eastern Railway, from Lillooet north to about 150-Mile House. All mineral occurrences of possible economic value, so far as they could be ascertained, were examined and a certain amount of prospecting was done. The deposits examined include clay, hydromagnesite, epsomite, sodium carbonate, chromite, molybdenite, manganese, nickel, a few gold, silver, and copper prospects, muscovite and peridot. The list is notable because of its diversity and because many of these minerals are not found as ores in more than one or two localities in Canada. Several of them are of exceptional geological interest, in that they are practically in process of formation to-day. This preliminary report is written, however, to call attention to their potential economic value rather than to discuss their geology and chemistry. Practically no shipments have been made from these deposits and yet some of them are surely a future asset to the country. Although the gold placers of the Cariboo to the northeast of this area have been the scene of much mining activity for more than fifty years, this district through which practically all travel to the goldfields passed, has remained unnoticed. This is partly because certain of the low-priced products found here had to await the building of a railway before they could be marketed at a profit, and many of them have become of value only within the last few years through the increased application of chemical and metallurgical research to industry, and the consequent increased use of certain chemicals and metals in manufacturing.

The Cariboo road, from Ashcroft, 220 miles north to Quesnel on the Fraser, has been for years the main artery of travel in this country. From Soda creek, 60 miles below Quesnel, there is a steamboat connection up the Fraser with the line of the

[1] By permission of the Director of the Geological Survey of Canada.

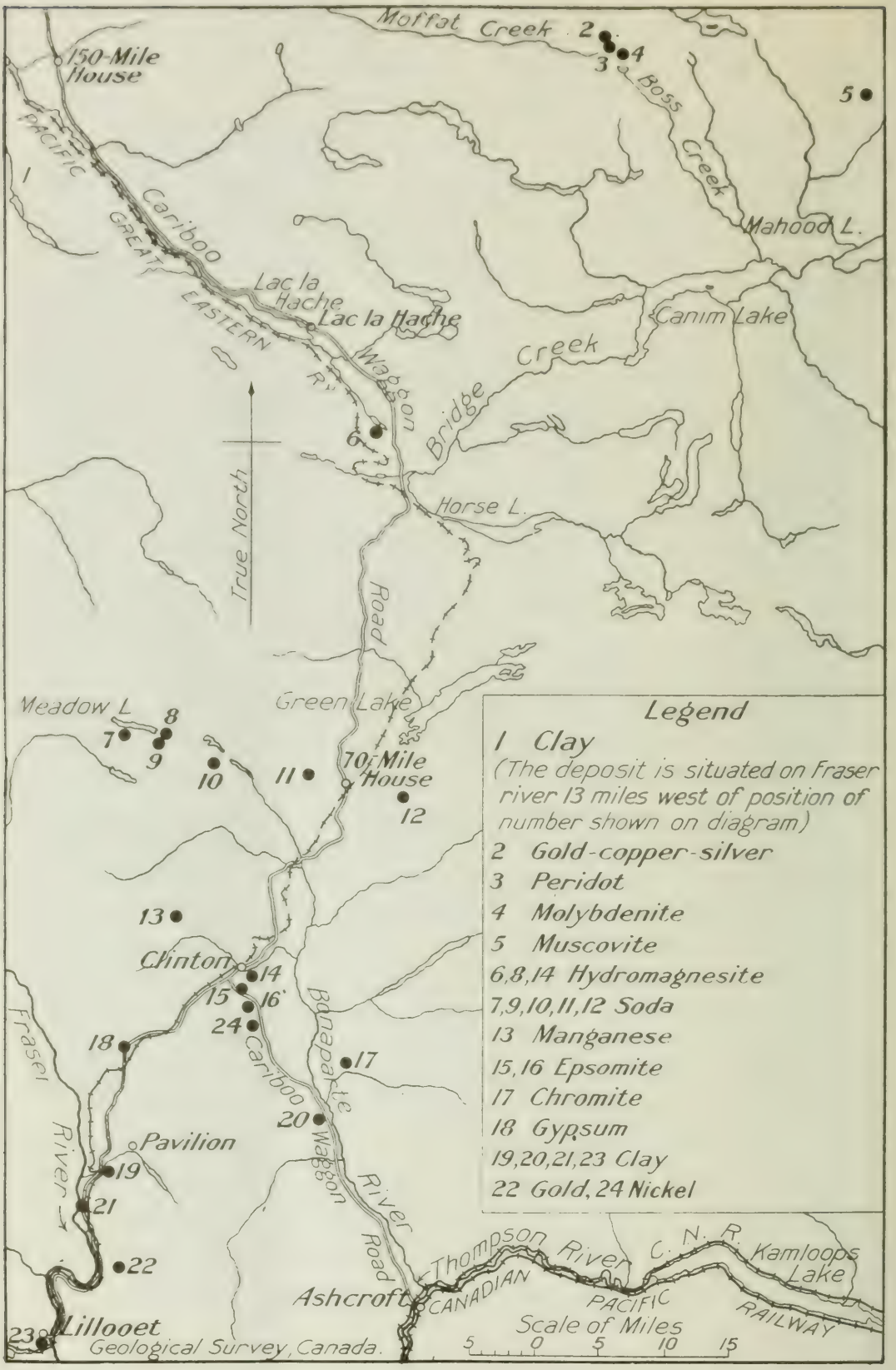

Fig. 1.—Mineral deposits in the Clinton and adjacent mining divisions British Columbia.

Grand Trunk Pacific at Prince George. A railway, the Pacific Great Eastern, is now being constructed from Squamish, a port near Vancouver, through Lillooet and Clinton, and from there north to Fort George. Trains have been operating from Squamish to Clinton for some time and the railhead is at present over 100 miles north of Clinton, or about 300 miles from Vancouver. There is a car ferry from Vancouver to Squamish. From Squamish to Lillooet the railway passes through the coast ranges. From there it follows the rugged Fraser canyon north for 28 miles and then cuts across a subsidiary mountain range to Clinton. From Clinton north it is on the interior plateau, a district that is truly plainlike in part, but most of which is made up of rounded hills and broad valleys. There is much open meadow country with comparatively thin forest covering in general, so that range cattle and horses are bred on a fairly large scale.

The rocks met with are briefly: (1) Glacial deposits: silts, gravels, boulder clays, conglomerates; (2) Tertiary lavas of Miocene age; (3) Conglomerates and shales of Oligocene age; (4) Granites and quartz diorites probably Eocene or late Cretaceous; (5) Tuffs of Cretaceous age; (6) Quartz diorite, etc., probably Jurassic; (7) The Cache Creek series of Carboniferous age consisting of an upper portion, which is mostly limestone, and a lower portion made up of quartzites, argillites, schists, altered volcanic rocks and bands of serpentine and limestone.

Clay.—This district is one of the few in Canada in which occurrences of residual clay have been found. There is a great dearth of workable deposits of kaolin and high grade fire clay in Canada, and as kaolins are to be looked for in such residual deposits, a special effort was made to examine and sample as many outcrops of residual clay as possible. Plate I shows a series of lavas that have been more or less altered to clay. This deposit is situated 17 miles above Lillooet in the Fraser canyon (Fig. 1, No. 21), and the picture illustrates the size of some of these clay banks. Samples were taken from different beds at this place, which lies on the railway line, and also from residual clays on the Fraser (Fig. 1, No. 19) and Chimney creek,

Plate I.—Residual clays, formed by decomposition of miocene lavas, at Seventeen-mile ranch, Fraser canyon.

bridge No. 1, as well as from a locality on the west side of Bonaparte river (Fig. 1, No. 20). Bedded clays were also collected near the Fraser at Lillooet (Fig. 1, No. 23) and 215 miles north. All these were tested in the ceramic laboratory of the Mines Branch under the direction of Mr. Joseph Keele. The bedded deposits proved to be building-brick clays. Three of the residual clays are not of commercial use. The clay from the deposit shown in Plate I cracked badly on drying and fused at a low temperature. Lack of refractory qualities, together with high stone content, condemned the clays at Pavilion and on the Bonaparte river. Only one residual clay was of high grade. This occurs in an outcrop of argillites and quartzites of the Cache Creek series west of the Fraser river at Chimney Creek bridge. Mr. Robert Gardner of Riske creek holds it under a quarry lease. The results of the laboratory tests on clay from this bank may be summarized as follows. The beds tested are numbered from top to bottom.

RESULTS OF TESTS ON CHIMNEY CREEK BRIDGE CLAY, FRASER RIVER

No.	Thickness in ft.	Colour Raw	Colour Burnt at Cone 5	Plasticity	Total per cent shrinkage at cone 5	Per cent absorption at cone 5	Temperature of softening or fusion	Remarks
1	3	White	Drab gray	Low	8	6	Cone 18 (1490° C.)	Contains 50 per cent rock fragments.
2	25	White & pink	Buff	Low	11	11	Cone 26 (1650° C.)	A number 3 fire clay about 25 per cent fresh rock.
3	2½	White & pink	Cream white	Low	15	17	Above Cone 30 (1730° C.)	This is a number 1 fire clay. The best in the bank.
4	25	Light buff	Drab gray	Fair	14	0.6	Cone 18 (1490° C.)	Resembles 2 in appearance with about same amount of fresh rock.

Cone 5 = 1230° C.

1. A sample of the washed clay fused at Cone 15 (1430° C.).

4. The clay ground to pass a 150 mesh screen had fair plasticity, but was rather short; it fused to a slag at cone 18.

It will be noticed that 27 feet out of the 55-ft. section can be considered fire clay, that is, fusing above cone 26, and of that, 2 to 3 feet is highly refractory. It would be difficult to quarry without including the other less refractory beds. According to Keele[2] "these clays as a whole might be worked for the manufacture of low-grade fire brick or mixed with more plastic clay for making sewer pipe. Crushed and washed they would yield some fine-grained clay for the manufacture of stoneware goods, but the yield of washed clay would probably be too small to repay that operation." The clays lie 15 miles by road over a stiff grade from the railway at Williams lake and the nearest water for washing purposes is 1,500 feet or so below, in the Fraser river. They cannot be looked on as of a commercial value, but the finding of fire clay here should encourage prospecting close to the railway line farther up river.

Prospecting.—High grade fire clays and kaolins are the only clays worth prospecting for in this district. They are generally white or cream-coloured and should be looked for on the sides of steep gorges like those of the Fraser river and its tributaries. The Lower Cache Creek quartzites and argillites which outcrop in the Fraser canyon from north of Chimney creek bridge up as far as Soda creek are the most promising rocks in which to search for clays of high grade.

There are other earthly deposits in the district which might be mistaken for clay; namely, talc, white volcanic ash and infusorial earth. They are distinguished from clay by their lack of plasticity. Talc is very soft and does not slake in water; white volcanic ash and infusorial earth are, as a rule, much lighter than an equal volume of clay. In residual clays the amount of non-slaking stony material in the clay, the thickness and character of overburden, and especially the distance from railways and markets, are among the factors which determine whether or not the deposit can be exploited economically. Samples representing the body of clay that is to be worked should be sent to the Mines Branch at Ottawa for testing before

[2] Laboratory Report by Mr. Joseph Keele, Mines Branch.

any money is spent on development. Blowpipe tests, and even quantitative chemical analyses, do not determine whether a clay is of commercial value.

HYDROMAGNESITE[3]

Fine-grained white to cream-coloured earths are found on the flat bottom land at Clinton, near Meadow and at Watson lakes, Fig. 1. Deposits are said to occur also at Riske creek and at 140-Mile House, but these were not visited. Upon analysis they proved to be made up very largely of hydrated carbonates of magnesium. Earthy outcrops of gypsum and calcite, resembling hydromagnesite almost exactly, occur at Kelly lake and at Clinton on the hillside above and east of the deposits of hydrated magnesium carbonate. Large deposits of very pure hydromagnesite occur at Atlin and have been described by Young.[4] It is also reported to occur in Ceylon. Although it has not been used on a large scale as yet in the industries, hydromagnesite can be utilized, if suitable methods of calcination are devised, as a source of the various products now made from magnesite, including magnesia for use as refractory linings for furnaces, part of the ingredients used in the manufacture of Sorel cement and other products. It is desirable that the raw product be as free as possible from lime, silica and the oxides of iron and aluminium. Magnesia containing a maximum of 3 to 4 per cent of silica, 6 to 8 per cent of iron, and 4 per cent of lime, has been used to advantage for refractory purposes, and of late, methods have been devised by which magnesia with a higher percentage of calcium can be used for the same purposes. For the making of Sorel cement, magnesia of a uniform chemical composition and low lime content is required.

The hydrated magnesium carbonates found in this district are, as a rule, of a whiter colour than the calcium compounds.

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[3] The writer is indebted to Mr. Carew Gibson for information concerning the deposits at Watson Lake, and to Mr. F. Calvert, of Oroville, for many analyses and information regarding the hydromagnesite, epsomite and sodium carbonate deposits.

[4] Young, G. A. "Hydromagnesite Deposits of Atlin, B. C." Sum. Rep., Geol. Surv. of Can. for 1915, pp. 50 to 61.

Plate II

Part of the hydromagnesite deposit at Meadow lake, showing circular masses rising above the general surface.

They slake and become very sticky when wetted. The analyses given in Table 1 show that they vary in their percentages of carbon dioxide and crystalline water and are not in all cases of the same composition as the mineral, hydromagnesite. The material is very fine-grained, partly coherent and slightly stratified in places, with flattened cavities between bedding planes. In many places there is an increase in the calcium and silica content with depth, and this is accompanied by a grayer or more yellowish colour and in places by increased coherence and more distinct stratification. The purer hydromagnesites occur as tabular or disc-shaped masses with nearly flat upper surfaces which are broken into somewhat circular, cauliflower-like humps, Plate II. The spaces between these may be a foot or more below the centre of the cauliflower and in certain cases contain huge boulders between which are large open spaces whose bottoms may be several feet below the hydromagnesite.

As far as could be determined from the few test pits dug in these deposits their bases are nearly flat with occasionally deeper parts. There are nodular shaped occurrences of gypsum and calcite near the hydromagnesite and it is possible that the latter also may occur in that form.

The composition of certain of these earths is given in the table below. Analyses 4 and 5 illustrate the increase in calcium content with depth. I have been informed by Mr. F. Calvert, who tested the Meadow lake deposit, that the change takes place rather abruptly at a depth of 2 feet in the Meadow lake deposit. This is true in general of the deposit at Watson lake. The silica content also increases with depth.

Amounts available.—In general it may be said that the purer hydromagnesites are flat deposits outcropping on low ground. The upper 1½ to 2½ feet is, in general, of high grade, but from that depth down the silica and lime contents are too high for commercial exploitation. The only known exception is one of the outcrops at Watson lake which is believed to be of good quality to a depth of 5 feet. Dr. K. A. Clark of the Mines Branch determined the 'apparent specific gravity' of lumps of this material as they were dug from the deposit at Watson lake as 1.22. This makes the weight of a cubic yard of the hydromagnesite as it lies in the deposit, including voids, 2,050 lbs. Tonnage was calculated from this factor on the supposition that only the material outcropping was of commercial value, and from such scanty data as to depth as were available. Figured on this basis there is about 7,000 tons of high grade material at Clinton, 25,000 tons at Watson lake and 180,000 tons at Meadow lake. Besides the better grade hydromagnesite there are large quantities of impure material in all three places.

Exploitation.—There has been no development of any of these deposits and, therefore, no data that can be used in computing the cost of developing and marketing them. The deposits are soft enough to be excavated by steam shovel, but it will be difficult to do so without the danger of including some of the high calcium material under it, which resembles it very

TABLE I—ANALYSES OF

	SiO_2	Insoluble including SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO
1. From middle of largest deposit at Clinton, 0 to 2 ft. from surface	2.30	....	0.63	0.13	....	41 60	0 22
2. Average of analyses of material taken from 5 pits in two largest areas at Meadow lake, 0 to 2 feet from surface.	1.22	....	0.67	0.18	0.63	40.56	1 26
3. Middle of largest area at Meadow lake, 0 to 3¼ ft. from surface	13.10	....	1.34	0.11	0.17	36.63	2.86
4. Same locality as 2, 3¼ to 5 ft. from surface	10.32	....	1.35	0.49	....	24.32	20.12
5. Impure magnesite near lake level 7, Meadow lake, 1 to 2 ft. from surface	....	36.78	1.54	0.84	0.59	20.14	9.20
6. From middle of southwesterly deposit at Watson lake, 0 to 4½ ft. from surface	....	6.36	0.20	0.12	....	41.06	1.62
7. From near middle of same deposit at Watson lake	10.24	....	0.38	0.16	....	39.33	2.06
8. From hole in east end of easterly deposit at Watson lake, 0 to 3 ft. from surface	....	4.62	0.16	0.16	....	43.17	1.14
9. From Watson lake, locality unknown	1.73	....	0.12	0.07	....	43.73	...
10. Average of 5 samples from 3 localities at Watson lake at depths of 1, 2 and in one case 5 ft. from surface	0.76	....	0.49	0.04	....	44.52	0
11. Deposit 1 mile northeast of Watson lake	....	8.62	0.33	0.57	....	36.70	1.54

Numbers 1, 3, 4, 5, 6, 7, and 8 analysed by Frederick Baridon, Mines Branch.

1. This was taken from middle of the best looking deposit on the flat at Clinton.

2. Analysis furnished by F. Calvert, of Stewart Calvert Co., Oroville, Washington, U.S.A.

HYDROMAGNESITE DEPOSITS

CO_2	SO_3	Cl.	Organic matter.	H_2O above 105°C.	H_2O below 105°C.	Total	Calcium carbonate.	Gypsum.	Magnesium carbonate plus water of crystallisation.
35.88	0.36	tr.	...	17.53	1.12	99.77	...	0.7	94.9
35.96	...	..	...	18.00	1.45	99.93	2.3	...	93.51
35.64	0.13	tr.	...	7.00	2.58	99.56	4.9	0.3	77.04
38.64	0.14	tr.	...	2.93	1.45	99.76	35.8	0.3	50.11
20.24	.07	tr.	...	6.80	3.52	99.72	16.4	0.2	36.22
38.04	.08	tr.	...	11.25	1.32	100.05	2.8	0.2	89.10
35.76	0.21	tr.	...	9.04	2.11	99.29	3.4	0.5	82.59
43.64	0.51	tr.	...	5.26	1.42	100.08	1.4	1.0	91.26
37.03	...	..	...	17.79	....	100.90	...	...	...

(50.65 loss on ignition)

31.08	0.18	tr.	3.10	14.86	2.21	99.19	2.5	0.3	82.47

9. Analysed by R. A. A. Johnston, Ann. Rep., G.S.C., Vol. XI, 1898, p. 11R.

10. Analysis furnished by the owner, A. E. Carew Gibson, of Vancouver.

closely. The Clinton and Watson lake deposits lie less than two miles from the railway grade and below it in elevation. The deposit at Meadow lake is 16 miles from the railway over a wagon road of easy grade. Vancouver is from about 200 to 260 miles by rail from the shipping points. If calcination could be effected at the deposits the weight that has to be transported would be reduced by about 60 per cent.

EPSOMITE

Epsomite or Epsom salts ($MgSO_4+7\ H_2O$) occurs in a small land-locked lake on the Ashcroft road about 1½ miles from Clinton station (Fig. 1, No. 15, and Plate III). Another and larger lake (Fig. 1, No. 16) 2 miles farther south, carries a brine varying in specific gravity from 10 to 18 degrees Baume.

Plate III

Epsomite lake at Clinton, B.C., showing wooden runway going to centre of lake, and piles of epsomite near shed on shore.

Similar lakes occur on Kruger[5] mountain, on the international boundary near Oroville, Washington. These are the only known epsomite deposits of commercial size in Canada. Epsomite is a translucent and well-crystallised salt when first excavated, but becomes white and powdery on exposure to the air It is used in medicine, in tanning and in the manufacture of textiles. Within the small lake at Clinton are circular areas of epsomite overlain by a few inches of water, and between them there is a soft mud containing a certain percentage of epsomite and hydromagnesite. One of these circles or 'pools' is flat on top and convex below, and is made up of layers, the upper almost pure epsomite, and lower ones carrying 1 to 5 per cent of sodium sulphate and a little mud. They vary in diameter to over 15 feet, and the greatest thickness is about 4 feet. Below them is more mud. This lake and those on Kruger mountain are owned and operated by the Stewart Calvert Co. of Oroville. At Clinton the salt is excavated by pick and shovel and taken in wheel-barrows over a wooden runway to the sides and there spread to dry (Plate III). Then after being screened it is sacked and shipped to the company's plant at Oroville, where it is redissolved, the impurities removed and the salt crystallised so as to produce a uniform product of small and even size in which shape it is put on the market. The smaller lake, which is the one being worked, covers an area of about 24 acres. If it be assumed that the salt in the 'pools' would, if combined, form a bed 9 inches thick over the surface of the lake, there would be about 50,000 tons of epsomite available.

SODIUM CARBONATE

A number of lakes without outlets lying on an east-west line about 22 miles north of Clinton (Fig. 1, Nos. 7, 9, 10, 11, 12) carry strong solutions, and in some cases crystallised deposits, of sodium carbonate.

Sodium carbonate[6] is marketed principally in three forms,

[5] Jenkins, Olaf P. "Spotted Lakes of Epsomite in Washington and British Columbia." Amer. Journ. Sci., Vol. XLVI, Nov. 1918, pp. 638-644.

[6] Wells, Roger C. "Sodium Salts in 1917." Mineral Resources of United States, 1917; Part II—23, pp. 305 to 341.

soda ash, Na_2CO_3; sal soda or washing soda, $Na_2CO_310H_2O$; and sodium bicarbonate, baking soda or saleratus, $NaHCO_3$. All of these can be produced from natural deposits, and sal soda is a common product of crystallisation in alkaline lakes, but a great deal of sodium carbonate is manufactured either from sodium sulphate, limestone and coal, by the Leblanc process, or from common salt, ammonia and carbon dioxide, by the Solvay process. The demand for, and production of, sodium carbonate have increased very greatly within the last decades, and it is used in so many industries that the demand for it will, without doubt, continue. Soda ash is used for producing certain reactions in a great many chemical industries. As sodium hydroxide it is utilised in the wood pulp and soap industries, and it is used directly in glass making and for manufacturing dyestuffs and explosives. Sodium bicarbonate is used in medicine, in cooking and for making effervescent drinks.

The soda lakes north of Clinton all lie on a flat, drift-covered, basaltic plateau, between elevations of from 3,500 to 3,800 feet above sea level. They are land-locked, with drainage areas that do not extend more than a few hundred yards from the shores, and are surrounded by low drift hills, in a few cases little more than 20 feet in elevation above the lake surface. The lakes, in some cases, merely contain solutions of sodium carbonate weak enough in places to permit the growth of vegetation, in others, the solution is strong and with an unpleasant odor and taste. Other lakes contain deposits of crystalline sodium carbonate as well as brine. Goodenough lake (Fig. 1, No. 7) is said to have a bed of salt from 3 to 8 inches thick over its bottom during the dry season. Last Chance lake (Fig. 1, No. 10), with an area of about 40 acres, is covered by a series of salt circles of exactly the same appearance as those of the epsomite lake at Clinton.

The composition of the salts from four lakes and of the brines from two are given in the following tables (II and III). The low percentages of calcium and magnesium in the salts and brines, and the presence of boron and phosphorus indicate that these

TABLE II—ANALYSES OF SALTS FROM SODA LAKES

		1.	2.	3.	4.
Soda	Na_2O	31.36	21.36		37.83
Potash	K_2O	trace	.....		0.05
Magnesia	MgO	0.04	.....		0.09
Silica	SiO_2	trace	0.01		.....
Alumina and	Al_2O_3,Fe_2O_3	trace	.....		.....
Iron	FeO				
Carbon dioxide	CO_2	22.08	15.46		26.70
Sulphur trioxide	SO_3	0.11	0.08		0.04
Phosphorus pentoxide	P_2O_5	.....	0.01		.....
Boron trioxide	BO_3	.....	trace		.....
Chlorine	Cl	trace	0.01		0.37
Water above 105° Cent.		0.84	63.03		0.61
Water below 105° Cent.		46.67	.....		33.98
		99.90	99.96		99.67

Hypothetical Combinations.

Sodium carbonate	53.21	35.54	35.96	64.34
Sodium bicarbonate	.....	1.34	.....	.....
Sodium sulphate	0.14	0.14	5.21	0.07
Sodium chloride	.....	0.02	0.33	0.28
Potassium chloride	.....	.....	.....	0.11
Magnesium chloride	.....	....	.....	0.24
Sodium metaborate	.....	trace	.....	.....
Sodium hydrogen ammonium phosphate	.....	0.02	.....	.....
Insoluble	.....	.....	.02	.....
Water	46.47	62.89	58.48	34.59
	99.82	99.95	100.00	99.63

1. From stockpile on shore of Goodenough lake near southwest end on Meadow lake, B.C. Analysed by Frederick Baridon, Mines Branch.

2. From deposit in Goodenough lake, analysed by R. A. A. Johnston, Ann. Rep., Geol. Surv. Can., 1918, Vol. XI., pp. 12, 13R.

3. From top of solid crust in Last Chance lake in northeast quarter, lot 1768, between 59-Mile House and Meadow lake. Per F. Calvert. 3.32 per cent. of the solid matter derived from the brine in this lake was found to be potash K_2O.

4. Manufactured soda, lake in lots 1792, 1793, 3½ miles west of 70-Mile House, owned by Pacific Coast Contractors, Ltd. Analysed by Frederick Baridon, Mines Branch.

TABLE III—ANALYSES OF BRINES FROM SODA LAKES

1,000 grains of water contains grains of:	1.	2.
Sodium, Na	18.3800	37.428
Potassium, K	trace	6.890
Calcium, Ca	trace	.016
Magnesium, Mg	0.0261	.037
Aluminium, Al	None	0.183
Silica, SiO_2		0.041
Carbonic acid, CO_3	22.6600	42.845
Bicarbonate acid, HCO_3	3.0600	10.731
Sulphuric acid, SO_4	0.0820	7.326
Chlorine, Cl	0.8590	7.902
Boric acid	None	
Phosphoric acid	.....	.771
Total	45.0671	114.170
Percentage of total solids (dried at 103°C.)	4.53	11.4
Specific gravity at 60° Fahr	1.044	1.108
Equivalent to degrees Baume	6.1°	

Hypothetical Combinations.

1. Sodium carbonate	38.4500	74.236
2. Sodium bicarbonate	4.0350	
3. Potassium carbonate		1.630
4. Magnesium carbonate	...	0.130
5. Magnesium bicarbonate	0.1571	
6. Calcium carbonate	...	0.041
7. Sodium chloride	1.4150	13.021
8. Sodium sulphate	0.1213	
9. Potassium sulphate		13.294
10. Sodium phosphate	...	0.222
11. Aluminum phosphate	...	0.825
12. Silica		0.041
13. Carbonic acid unaccounted for	0.8893	10.731
	45.0677	114.171

1. Brine from lake 5 miles east of 70-Mile House, just southeast of lot 1514, owned by D. B. Hutchinson; analysed by Frederick Baridon, Mines Branch.

2. Brine from Goodenough lake, analysed by F. G. Wait, Ann. Rep., Geol. Surv. Can., Vol. XI, 1898, pp. 48 to 50R.

brines are of deepseated rather than atmospheric origin, that is, they were brought up by ascending waters associated with an igneous intrusion or extrusion.[7] This is confirmed by their close association with extensive basaltic beds which, in places, contain sodium minerals such as analcite in amygdaloidal cavities, and by the occurrence of the principal lakes in an approximately straight line, presumably the site of a fault line, across about 25 miles of the plateau.

Some of the sodium carbonate has been excavated from Goodenough lake and a pile of about 16 cubic yards is still to be seen on the lake shore. At a lake covering about 85 acres, 4 miles west of 70-Mile House and the railway (Fig. 1, No. 11), the Pacific Coast Contractors, Ltd., of Vancouver, is manufacturing sodium carbonate from a brine carrying about 6 per cent of solid matter. An analysis of the manufactured product is given in Table II. The brine is concentrated by boiling in a large open concrete tank. Wood fuel is used as there is a large supply. The railway is 4 miles away and the shipping point about 230 miles by rail from Vancouver. The company began operations in 1918 and their capacity in September was about 3 tons, expressed in soda ash, per day. They calculate that there is more than 60,000 tons of sodium carbonate available in this lake, and they own a smaller lake of the same character close by. There should be a future for this industry in Canada.

MOLYBDENITE

Molybdenite, like chromite, manganese and nickel, is used in the manufacture of special alloy steels. As many of these steels are used in the making of ordnance and munitions, the demand for the four metals increased continually during the war, and a shortage in chromium and molybdenum ore caused their prices to go very high and the Canadian and other governments to offer special inducements for their production. Thus the price of molybdenite in 1918 fell from $2.25 to 87 cents per

[7] Gauthier, Armand. "Caractères Differentiels des Eaux de Source d'Origine Superficielle ou Meteorique." Comptes Rendues, Vol. 150, 1910, pp. 436-441.

pound of molybdenite content on the New York market. The signing of the armistice naturally caused a drop in prices, and in some instances there were no sales for long periods. It is the opinion, however, of some of those who have been handling molybdenite ore for the last few years that there will be sales for the Canadian production at about 75 cents per pound for 85 per cent concentrates if a steady supply can be assured. Other 'war minerals' treated in this article, such as chromium and muscovite, have gone through the same fluctuation in prices.

Molybdenite was discovered in the fall of 1917 on Timothy mountain (Plate V), an outlying ridge of the Cariboo mountains, which lies about 35 miles northeast of the south end of Lac la Hache and about 16 miles north of Canim lake. The location (Fig. 1, No. 4), is approximate. The molybdenite occurs in a series of parallel fissure veins on the northeast flank of the mountain.

The ore mineral is molybdenite, the dark gray sulphide of molybdenum (MoS_2) carrying 60 per cent of molybdenum. The weathered parts of the orebodies contain molybdite, the yellow fibrous hydrated ferrous molybdate ($Fe_2O_3.2MoO_3 7\frac{1}{4}H_2O$) carrying 40 per cent of molybdenum. The gangue minerals are pyrite, orthoclase, quartz, sericite, biotite and epidote. The country rock is a gray medium-grained granitoid quartz diorite made up of hornblende and labradorite with minor amounts of orthoclase and quartz, and also some magnetite and apatite. A number of dark green basic dykes or inclusions are found associated with the ores. There are also dykes of pegmatite and aplite.

The veins are more or less banded fissure fillings, orthoclase and pyrite lying on the outside, then molybdenite, and quartz in the centre. Molybdenite and quartz are in most cases the only filling, and bands of nearly pure molybdenite, half an inch to an inch across, are not uncommon. Close to the fissures the country rock has been replaced by quartz, sericite, biotite, epidote and pyrite, in the order named. Quartz was, therefore, deposited at two distinct periods. Pyrite is more abundant as

a replacement mineral outside the veins. Molybdenite, on the other hand, is found inside the veins rather than disseminated in the country rock. The veins vary in width from one inch to three feet and lie in a belt striking S. 37° E. and dipping southwest at angles of from 25° to nearly 90°. The main belt of veins lies on the southeast side of a creek valley and the outcrops have been uncovered at intervals for a horizontal distance of 1,900 feet. The greatest proven distance between veins across the strike is 75 feet and the eastern outcrops are 450 feet in elevation above those at the creek Other outcrops of veins lie 500 feet northwest in the direction of the strike, and a shattered zone of country rock, 40 feet across, with numerous small veins lies 800 feet down the creek. There has evidently not been any very serious displacement of the ores, although many small faults were observed.

The molybdenite has been deposited in the fissure veins by hot ascending solutions at points not far from the parent magmatic mass. This is proved by the presence of orthoclase, epidote and the other gangue minerals associated with the ore. Pegmatite dykes are of frequent occurrence in the neighbourhood, and the ore which was found lying within one of them appeared to be of slightly later formation. Veins of tourmaline and epidote are commonly associated with the pegmatite. The origin of the gold-silver-copper veins about two miles to the northeast (Fig. 1, No. 2) has evidently been similar, but they were probably deposited farther away from the parent magma.

Very little could be learned regarding ore values because of the lack of underground workings. The ore is in places impoverished by weathering down to four feet from the surface. As far as could be determined by inspection, ore values average the same in the outcrops near the creek as on the hillside 450 feet above. The writer took a sample across an orebody 30 inches wide, 4 feet below the surface, consisting of two quartz veins, one 12 and the other 6 inches wide, with altered country rock and vein matter between them. The assay by Frederick Baridon of the Mines Branch yielded molybdenite 1.43 per

cent (0.86 per cent of molybdenum) and no copper. There is much variation in values, of course, but the above is probably the approximate average value just below the first few feet of weathered material in many of the open cuts within the main belt of veins.

Five claims have been staked to cover the known outcrops of ore since the first discovery in 1917. The chief owner of these claims is William J. Ryan of Lac la Hache. Three or four entries 15 to 30 feet deep, a shaft 8 x 9 x 8 feet, and numerous open cuts represent the work done up to September, 1918, which was rightly planned to show up the extent of the outcrops before proceeding to do much work underground.

In February, 1918, the Mines Branch received 761 pounds of ore from this property for concentration. Of this 253 pounds averaged 58.88 per cent and 509 pounds 16.67 per cent of molybdenite. The net price paid for this after deducting concentrating charges, etc., was $374. Railway freight charges paid by the shipper amounted to $15.75. In addition, some 200 pounds running 75 per cent MoS_2 was sold elsewhere for $100. Development of this property can be done by drifting along the strike of the veins from outcrops near the creek bottom. There is plenty of spruce and balsam available for mining purposes. At present the claims are connected by about 20 miles of pack trail and 15 miles of road to the railway grade at Lac la Hache. The trail follows a good grade all the way except in the last two miles where it crosses the mountain. Lac la Hache will be about 270 miles by rail from Vancouver when construction is completed.

CHROMITE

Outcrops of serpentine carrying bodies of chromite occur on Scottie creek (Fig. 1, No. 17) which enters Bonaparte river from the east about 19 miles north of Ashcroft. The occurrence is on Chrome creek, a side stream about one-half mile north of Scottie creek and four miles above where that stream enters the Bonaparte. The deposit was discovered in 1901 by Mike Ahearn, a local prospector, but no serious attempt was

made to develop it until the anticipated shortage and constantly rising price of chrome in 1918 stimulated the development of newly discovered orebodies.

Plate IV.—Chromite-bearing serpentine on Scotty creek.

The ore on Scottie creek is the chrome picotite variety of chromite carrying 55.9 per cent of chromic oxide. A sample of the mineral was analysed and examined by R. A. A. Johnston[8] in 1901. Later he discovered that the chromite carried dia-

[8] Ann. Rep., Geol. Surv. Can., Vol. XIII, 1900, pp. 11 to 12R, Ottawa, 1903.

monds,[9] though not of commercial size. The country rock is dense dark green, and light yellowish green, serpentine, and the ore occurs in the serpentine in bodies of irregular shape and with no definite arrangement. The serpentine, which is of Lower Cache Creek age, outcrops in cliffs up to 60 feet high on the steep slopes on either side of Chrome creek (Plate IV). The outcrops are included within an area of about 50 acres and the greatest vertical difference between outcrops is a little over 200 feet. To the southwest they are succeeded by Tertiary lavas. On all other sides the rocks are covered over large areas by glacial drift. To the south the lavas lie below them in elevation. No information as to structure could be obtained because there were no other outcrops. The serpentine has been much faulted. It occurs in Cache Creek rocks to the west and north in bands from 100 to about 200 feet thick. The occurrence on Scottie creek may be a closely folded band, and it is unlikely that it is of very great thickness.

The orebodies uncovered so far have been small. At the northern end of the outcrops a tabular orebody 15 feet long, 8 to 20 feet wide and 8 inches thick, was uncovered near the surface. About 150 tons of ore were taken in one place from an open cut 80 feet long and about 5 feet deep; the ore varied in width from a few inches to a few feet.

Development.—A number of claims have been staked by Mr. Bryson of Pavilion, B.C., and by Stewart Clavert Co. of Oroville, Washington. The Bryson claims were leased by Stewart Calvert Co. in the summer of 1918. There were four small open cuts and a crosscut tunnel 46 feet below the surface on the chrome property in July, 1918. From 600 to 900 cubic yards of excavation had been done. About 200 tons of ore had been produced; 150 tons averaged about 40 per cent chromic oxide, and 50 tons were of lower grade. There are a few hundred tons in sight. In July, 1918, no ore had been shipped and construction on a road connecting the property with the Ashcroft to Clinton road

[9] Summary Report, Geol. Surv. for 1911, p. 360.

had just begun. If this road is finished the ore will be 24 miles by road from the Canadian Pacific Railway at Ashcroft.

GOLD-COPPER-SILVER

On the summit of Timothy mountain, two miles northwest of the molybdenite claims (Fig. 1, No. 2) and in a gulch on its eastern flank, gold, silver and copper values have been found in veins and shear zones lying in the same mass of quartz diorite as the molybdenite. The ore minerals are chalcopyrite, bornite, pyrite, galena and sphalerite, in a gangue of quartz. Dykes of dark green augite andesites and pegmatite occur near the ores. The ores lie either in quartz veins which are, as a rule, within shear zones of quartz diorite, or are disseminated through the basic dykes. A number of nearly parallel veins lie in a belt of sheared quartz diorite 25 to 30 feet wide on the summit of the mountain. The general strike is E. 42° S. The belt has been proved for about 700 feet along the strike. About one-quarter of a mile to the east the ores lie in shear zones striking east-west and crossing the first. The shattered zones are from 5 to 50 feet wide although the orebodies are much smaller. The claims are owned by William J. Ryan. A shaft 6 x 6 x 25 feet, a short tunnel and numerous open cuts have been made on the veins. The following assay results were given me by the owner:

(1) Picked sample of ore from the shaft: gold $7.00 per ton, silver 20 oz. per ton, copper 2 per cent, lead 25 per cent. and zinc 20 per cent.

(2) Bornite from middle vein of shaft: gold $44.00, silver 30 oz., copper 22 per cent.

(3) Chalcopyrite from hole 20 feet north of shaft: gold $17, silver 28 oz., copper 18½ per cent.

(4) Bornite from prospect ¼ mile to the east: gold $10.00, silver 7 oz., copper 5 per cent.

Two assays of pyrite from a gulch 500 yards further east and 900 feet lower in elevation gave $5.00 gold, 2 oz. silver, and $10.00 gold, 4 oz. silver, respectively, per ton. Conditions for development and transportation are the same as for the molybdenite, but drainage of underground workings on the summit claims will be more difficult.

Gold values have been found also in Fraser canyon, north of Lillooet. On Eleven-Mile creek (Fig. 1, No. 22) there are sheared carbonaceous Cache Creek argillites out of which the siliceous material has been leached. They lie not far from a granite contact. The shear zones vary up to 10 and 12 feet in width and strike N. 12° W. with a steep dip. Mr. A. Donaghey of the Eleven-Mile ranch had assays made of a sample from this place which yielded $3.20 in gold and some silver. The carbon content of the sample was 6.8 per cent. A sample taken by the writer across 4 feet of one of the zones did not contain either gold or silver and had a carbon content of 7.42. F. and W. Dillon, of MacKinnon, B.C., own claims to the east of the last but they were not visited. Values are said to occur in veins of quartz containing pyrite and chalcopyrite. An assay of a sample across a 3-ft. vein yielded 0.14 oz. of gold, 2.4 oz. of silver and 42 per cent of copper.

At the Big Slide mine[10] which is situated on the banks of the Fraser at the mouth of Kelly creek, there are quartz veins carrying pyrite and chalcopyrite. A ten-stamp mill with chlorinating plant was erected here in 1886 and some underground work done. A sample of the concentrate taken by Dawson from the mill in 1887 assayed 0.408 oz. of gold and 0.933 oz. of silver to the ton. The mine was only in operation for a few months. It is in an almost inaccessible place at the bottom of the canyon. Two of these occurrences and probably the MacKinnon claims lie in the neighbourhood of bodies of granite that outcrop in long narrow strips parallel to the strike of the formations in or near Fraser canyon. The rocks lying

[10] Dawson, G. M. "Report on the Kamloops Map Sheet, British Columbia." Ann. Rep., Geol. Surv. of Can., Vol. VII, 1894, pp. 339-341B.

near the contact of these granitic bodies should be favourable ground for further prospecting.

MANGANESE

A prospect carrying manganese ore is situated at the foot of the Marble mountains 10 miles northeast of Clinton (Fig. 1, No. 13). About 37 feet of quartzite and argillite of the Cache Creek series is exposed in an open cut, and about 20 feet of the quartzite is cut by quartz stringers and impregnated in an irregular manner with psilomelane, manganite and pyrolusite. There has been some concentration of the ore by weathering of the country rock. A sample was taken across 15 feet of the best looking part of the beds to include from 1 to 4 feet from the surface. The results of an assay in the laboratory of the Mines Branch were manganese 7.57 per cent, silica 82.57 per cent, phosphorous 0.18 per cent. This ore is exposed in an open cut 38 x 4 x 5 to 7 feet. No other outcrops of the ore were seen.

NICKEL

About 4½ miles south of Clinton, half a mile west of the Ashcroft road and 500 feet above it, there is an outcrop of a calcareous quartz rock carrying a green nickeliferous silicate.

The rock is foliated and the green mineral which is of later origin than the quartz and calcite lies in parallel bands through it. The outcrop is 25 feet by 10 feet in extent, and 200 feet south there is an outcrop of quartz. There are a number of boulders along the side hill for half a mile north, but no other outcrops have been discovered. An assay of a sample taken at intervals across the 25-ft. outcrop was made by H. V. Ellsworth of the Geological Survey and yielded 0.11 per cent nickel and 0.17 per cent Al_2O_3, the chromium being present in the form of minute grains of chromite. The claims are owned by John Ridner and J. W. Byrd of Clinton.

MUSCOVITE

Muscovite is one of the minerals for which an unusual demand existed at the time the field work for this report was

being done. The writer, therefore, visited an occurrence of muscovite in the Clearwater mountains north of Canim lake. The location (Fig. 1, No. 5) is approximate only. The mica occurs in a series of parallel pegmatite dykes from 5 to 25 feet wide intruded into mica schist. The dykes strike about E. 53° S. and dip 54° to the northeast. They follow the planes of schistosity of the mica and in places cut across them. The mica crystals occur in bands in the pegmatite, the bands being a

Plate V.—Cone-shaped hills of basalt containing peridot, Timothy mountain.

foot in width in places. Individual crystals vary from 1 to 12 inches in greatest dimension and their thickness is about one-third their length. In one place 6- to 12-inch crystals were seen for a distance of 100 feet along the strike of the easterly dyke; in one other place in a dyke parallel to the last, 6-inch crystals were found. All other occurrences were 3 inches or under and much of the outcrop was barren. The mica has a yellowish

stain, much of which is due to weathering and will disappear with depth. The dyke has been subjected to earth stresses and much of the mica is recrystallised into wedges or fractured in such a way that only a small part of the crystals can be used. The conditions will continue downwards. In this, as in most mica occurrences, only actual development work will prove whether marketable mica is present in paying quantities. Although this occurrence is just above the timber line, approximately 6,500 feet in elevation there is plenty of timber for mining purposes a few hundred feet down the ridge. Before mica can be profitably shipped from here about $800 should be spent on a pack trail to the east end of Canim lake. A heavily laden pack train should then be able to make the round trip twice a week for at least three months every year. According to information received at the lake the charges on freight 20 miles by boat down the lake and 25 miles from there to the railway, would be about 1¼ cents per pound.

PERIDOT

Peridot, the precious form of olivine, is found in two cone-shaped hills on Timothy mountain (Plate V) near the molybdenite claims (Fig. 1, No. 3). The stones occur in coarsely crystalline masses that lie in a basaltic matrix near the point of extension of the basalt. The rock underlying the basalt is quartz diorite and masses of that rock, some of them very much altered, others fresh, are found with the olivine-bearing masses. The stones are of a yellowish green to pale and dark green colour, and certain of them that have been cut, have made very fine gems. So far, however, no firm in Canada or in the United States has been found that will undertake to cut these stones, although they are very widely used and are a popular form of jewelry. It is to be hoped that this, the only gem locality of commercial importance in Canada, will be developed, and that some firm will have the enterprise to prepare the stones for the market.

THE NEW ZINC AND LEAD FIELDS OF GASPÉ PENINSULA

By Adhemar Mailhiot

(Annual Meeting, Montreal, March, 1919)

The region to which this paper has reference is situated at the head of the Brandy and Berry Mountain creeks, tributaries of the Great Cascapedia river, and constitutes the northern part of the projected township of Lemieux in the county of Gaspé. It is 40 miles in a straight line from the mouth of the Great Cascapedia river, which flows into the Baie des Chaleurs, and 30 miles from the mouth of the Ste. Anne river, which flows into the River St. Lawrence.

Access to the region is at present only feasible by wagon trail from Cascapedia, a railway point on the Quebec Oriental, a local railway, some 60 miles east of Matapedia on the Intercolonial system of the Canadian Government railways.

The discovery of the zinc and lead deposits was made in the autumn of 1910 at the spot where the present shaft of Messrs. Lyall and Beidelman is situated on a hill some hundred feet from the right bank of the Berry Mountain creek. The discovery claim was staked by James McKinley, in the name of the New Richmond Prospecting and Mining Company (afterwards the North America Mining Company), which did some prospecting work during the following years. In 1915, Messrs. Lyall, Maher and Beidelman acquired a lease of the property and at once commenced mining operations. Since 1915, all the lots in the vicinity of the original deposit have been staked by one or the other company.

The projected township of Lemieux has an area of 150 square miles. The group of staked claims occupies the northern part of this township and forms a strip of land about 150 chains wide and 320 chains long. The aggregate area is about 7 square miles.

There are in existence no reliable maps of the various rivers and streams of Gaspé peninsula and especially of those falling

into the Baie des Chaleurs and Gulf of St. Lawrence. Rough sketches of some of the more important branches may be found on the plans made by surveyors who went through the region looking for timber; but, as they have never been correlated, they are far from satisfactory.

WATER SUPPLY

Owing to the torrential character of the Berry Mountain and Brandy creeks, their flow varies greatly from one season to another. The slopes of these creeks and of their tributaries are very steep and, consequently, the slightest atmospheric precipitation at once increases their flow, while a short rainless spell suffices to dry them up. The Great Cascapedia river itself is also subject to many fluctuations from one season to another, but its flow is good throughout the year.

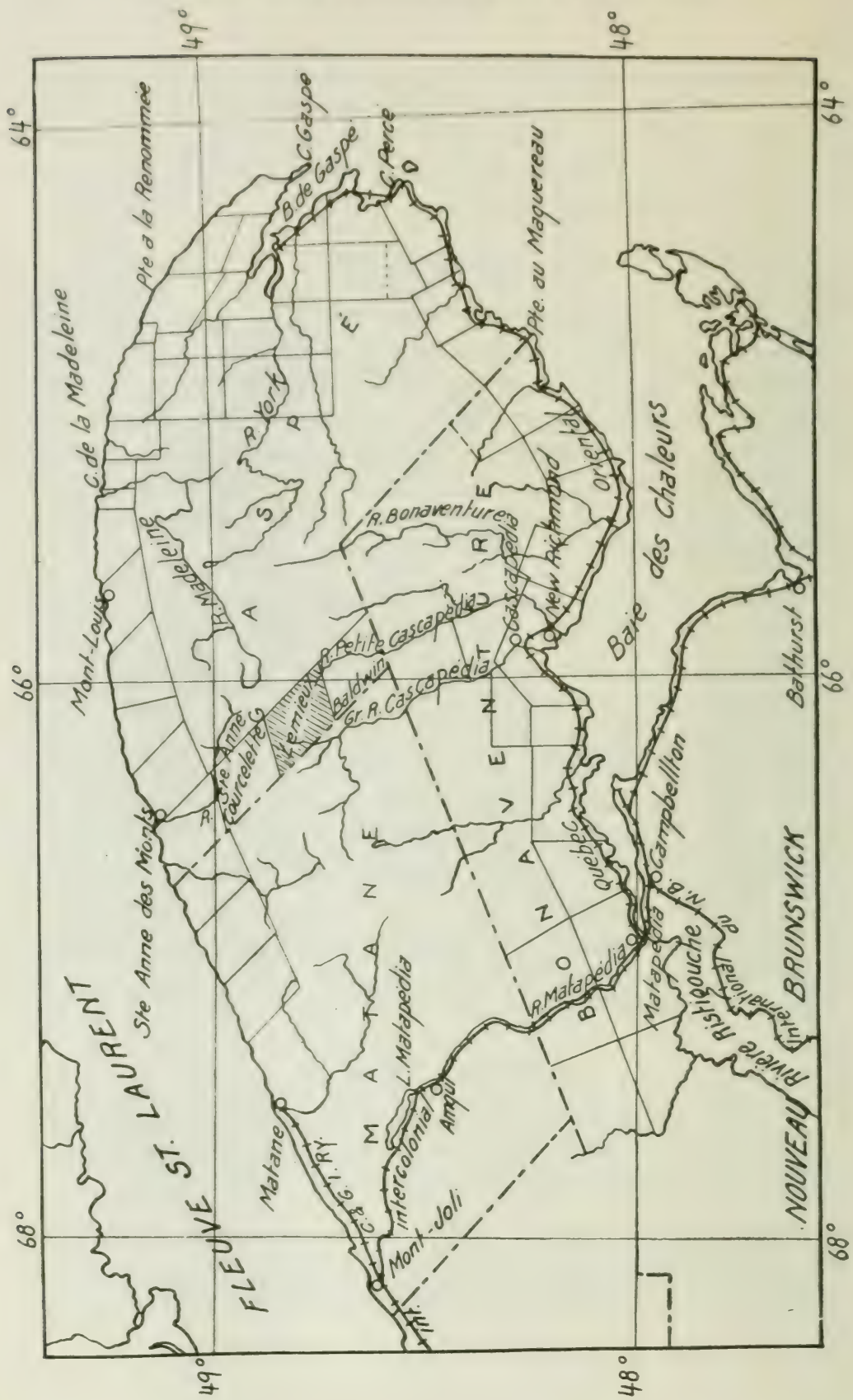
Lake Ste. Anne, about six miles east of the Federal mine, is the most important sheet of water in the region. It is four miles long with an average width of a mile, and its outlet is the river of the same name which flows towards the River St. Lawrence. About 12 miles below the lake, the Ste. Anne river, owing to the serpentine mass of Mount Albert, only partially cut away by fluvial erosion, drops vertically in falls 60 feet high, and below the falls runs through a fine and deep gorge, a quarter of a mile long, whose perpendicular walls rise more than 200 feet above the river.

The lake might perhaps serve as storage basin for regulating the river's flow and from the falls could then be developed sufficient electric power for extensive works.

MINING CONDITIONS

The Federal mine, the only one that has done mining work of any importance in the region, has so far not shipped any ore, although it has been in continuous operation since 1915.

Lack of transportation facilities from the mine to the railway is the sole reason that prevented the company from shipping ore. At present there are two carloads of hand-picked ore


64°
49°
48°
66°
68°
C. de la Madeleine
Pte à la Renommée
B. de Gaspé
C. Gaspé
C. Perce
Pte. au Maquereau
Mont-Louis
R. Madeleine
R. York
R. Bonaventure
New Richmond
Oriental
Baie des Chaleurs
Bathurst
Petite Cascapedia
Gr. R. Cascapedia
Baldwin
Ste Anne Gaurelette
Ste Anne des Monts
FLEUVE ST. LAURENT
Malbaie
C.P.R.
Intercolonial Ry.
L. Malapedia
R. Malapedia
Québec
Campbellton
N.B.
Matapedia
Restigouche
International
Rivière
NOUVEAU BRUNSWICK
Mont-Joli

ready to be sent to the smelter and not less than 9,000 tons of ore ready to be treated by concentration. The company is likewise waiting until a good road is made to erect a concentrating plant.

Road building will not be unduly costly as it involves practically no rock work, being a water gradient averaging less than 50 feet per mile to the base of the 400-foot hill at the mine.

There is an almost complete dearth of local labour for mining in this part of the country where the inhabitants are accustomed to farm work, cod-fishing, or lumbering. The miners employed in getting out the ore, as well as the machinists and blacksmiths, come from Nova Scotian mining centres; nevertheless, the Federal mine has undertaken to train local labour by endeavouring to give the men a taste for and skill in mining, and it hopes soon to be able to do without skilled workmen from outside the district.

The cost at the mine of provisions and supplies required for operations is very high, owing to the excessive cost of transportation from the railway station to the mine over a bad road. Supplies are generally sent in during the winter when transportation is cheaper.

GENERAL GEOLOGY

The Gaspé peninsula forms part of that geological province which American geologists call "Acadia," and which comprises the entire area now occupied by the Appalachians from the Gulf of Mexico to Newfoundland and Labrador, and from the River St. Lawrence, the Great Lakes and the Mississippi on the one side, to the shores of the Atlantic Ocean on the other. This peninsula constitutes the northern extremity of the great system of the Appalachian folds. As part of the Appalachian system, the Gaspé peninsula consists almost exclusively of Paleozoic rocks. The Notre Dame or Shickshock mountains, forming the elevated plateau of the peninsula's interior (altitude 3,000 to 4,200 feet) occupy the northern portion and contain patches of mica schists, jaspilites and epidotic gneiss, which

evidently constitute the basement of the Cambrian schists, but it has never been established that these rocks are pre-Cambrian. Many masses of peridotite, serpentine, and granite are found there. During the Paleozoic period, this part of the earth's crust was subjected to local and irregular movements; it was crumpled at various times and shoved to the northwest against the Laurentian plateau at the period of the great movements which gave rise to the Appalachians. These overthrusts are frequently masked by a mantle of more recent deposits.

The Gaspé peninsula seems to have escaped the eroding action of the great continental glaciers. Glacial deposits and striæ are scattered and correspond only to the flow from local glaciers starting from the mountains in the interior.

During, and after, the Appalachian deformation, the Devonian shales were intruded by the plutonic rocks now occupying the greater part of the region studied in this paper. We have subdivided the latter into three principal groups from north to south, namely: the granite porphyries, the syenites and the basic igneous rocks. As we did not find them in contact with one another, we are unable to state definitely their order of succession. Judging by their attitude, however, we have reason to believe that these igneous masses forced their way through the sedimentary rocks in an order of decreasing basicity, namely: first of all, invasion and flow of the basic igneous rocks; then intrusion in a batholithic form of coarse-grained syenites; and finally the volcanic activity ended with the flow of granite porphyries, giving rise to the formation of veins of mineralized quartz intersecting the sedimentary schists.

The age of the sedimentary rocks has been determined as belonging to the Grande Grève formation.

ECONOMIC GEOLOGY

Geographic Distribution.—The deposits of blende and galena, so far discovered in this region, consist of some veins outcropping on blocks A, D, and F, mined by Messrs. Lyall and Beidelman, and on Block L, the property of the North

America Mining Company. The greater number of these veins runs directly northeast-southwest, although we found others striking across them. They intersect all the schists with dips varying between 70° and 90°. Clearing a certain area of ground around the shaft of the Federal mine revealed some of these veins; others outcrop along the mine road where it runs around the hill.

Metalliferous Veins and Workings.—The mineralized veins contain zinc-blende, galena and some scattered grains of chalcopyrite and pyrite. The gangue forming the filling of the fissures consists of white and amethystine quartz and dolomite. The walls sometimes, as in the Federal mine, are formed by a breccia whose angular elements have been more or less altered and transformed into hornfels by the mineralizing solutions. The same applies to the country rock.

In places the filling is in distinct parallel veins or in intersecting veins, and, in other places, the mineralization lies in the spaces between the fragments of the breccia of the crushed zone.

Portions of veins, very well banded, are found in which the streaks follow one another in regular order and where the ores are in a definite order from the walls to the centre of the vein, but the banding is often very irregular or completely lacking and the veins are formed of large intergrown crystals which have crystallized simultaneously. In the veins with a well-defined banding there are frequently fine crystalline faces turned towards the centre of the vein; this phenomenon occurs more often in the amethystine quartz whose elongated crystals are developed normally to the walls and have a comblike structure. Sometimes also the extremities of the crystals point towards the interior of a cavity and form druses lined with fine crystals. The sulphides, both galena and zinc blende, are irregularly disseminated in the veins or form concentrated pockets.

The most developed claim of the region is block H. It is a portion of the claim staked by James McKinley in 1910. It now belongs to Messrs. Lyall and Beidelman. The work

done on this claim consists of a vertical shaft 160 feet deep sunk in the deposit and a drift at the depth of 100 feet, following the direction of the vein, about N. 40° E. for a length of 1,700 feet and opening on the side of the hill. The vein is 12 feet wide. The other work done on the claim consists of prospecting trenches for uncovering the metalliferous veins outcropping at the surface. Several outcrops occur in the cleared area around the shaft.

Origin of the Deposits.—Judging by the attitude of the deposits and the mineralogical association of the ores and gangue, we may conclude that the metallic sulphides zinc-blende, galena and chalcopyrite were deposited by ascending heated solutions containing metallic substances derived from igneous emanations. The appearance of the minerals in the shape of fillings in fissures, and the trend of the veins, often very well banded and sometimes presenting combed and drusy structures, clearly show that the deposits are of aqueous origin. The absence of the minerals characterizing the zones of metamorphic contact, the deep zones and the superficial zones, lead us to believe that the sulphides were deposited at intermediate depths.

At the time of the Devonian orogenic upheaval, which gave rise to the Shickshock range, the sedimentary rocks of the region were fissured, crushed and considerably displaced and altered. At the same time, the basic eruptive masses, the syenites and the granite porphyries were successively forcing their way through the open fissures or following new fractures in all directions. (The most important fissures, from an economic standpoint, are connected with the intrusion of masses of granite porphyry.) The syenite masses were cooled under a thick cover of sedimentary strata which the subsequent erosion partially removed. It seems that a considerable period must have elapsed between the syenite intrusion and the next disturbance, and it is probable that erosion had removed a great part of the sediments covering the syenitic masses when the flow of granite porphyries occurred.

The upward shove of the igneous mass probably caused compression strains immediately before the intrusion of the

granite porphyries. Several fissures, due to crushing and breaks, were produced in the formations covering the batholith. The molten rock with its gases and precursory solutions penetrated the fissures of the rocks of the hanging wall and caused the metamorphism of the schists and the formation of quartz veins.

The system of fissures resulting from the decrease of local tension and contraction strains in the rocks of the hanging-wall and in the subjacent batholith itself offered channels for the circulation of the mineralizing solutions. Solutions, caused and generated by the batholithic intrusion, ascended from great depths and deposited the elements they held in solution, lead, zinc, and copper, in the shape of metallic sulphides in a quartz gangue. The first solutions, at a very high temperature and under very strong pressure were highly silicious and deposited quartz and dolomite in the fissures and sometimes attacked the walls. These solutions were soon followed by other metalliferous ores containing chiefly galena, zinc-blende and a little chalcopyrite. The forced ascension of these solutions caused a widening of the fissures in certain places by producing a crumbling of the walls. This debris was cemented with quartz and dolomite and constitutes the breccia found in the hanging-wall of the Federal mine.

Depth of the Deposits.—None of the deposits prospected or mined has been examined to a greater depth than 160 feet, and the question of their continuation in depth is of great interest.

As the deposits are fillings of great fractures of the earth's crust, it would seem that they must go down to the base of the slaty sedimentary rocks. At the slight depth reached some veins show an increase in the volume of ore, while its character remains the same. There are some outcrops of ore at short distances from each other in plan, but between which are differences in elevation of several hundred feet and it is almost certain that the highest deposits go down in depth at least to the level of the lowest ones. Some veins on block H have been

followed for distances of about 3,000 feet, and it is probable that they extend still further under the cover of superficial deposits. Then the natural inference is that these veins must go down to considerable depths, for it is generally admitted that the length of a fissure is proportionate to a certain extent to its depth.

According to Mr. Walter Harvey Weed, who visited the property owned by Messrs. Lyall and Beidelman in the summer 1918, "the geological evidence indicates that the ore will extend a great distance downward. A depth of 1,500 feet for this oreshoot is quite possible." And he adds: "The property is of value and from the evidence at hand may be considered of very great possible value; it may make one of the great zinc mines of the country."

Present and Future Conditions of the District.—At present, two operators only are interested in the mining claims of the district, namely: Messrs. Lyall and Beidelman, and the North America Mining Company. The former has been mining for two years on blocks H, D, and E. They have completed a drift about 1,700 feet long, and all the ore taken out is in dumps ready for concentration. Lack of communication has so far delayed the construction of a concentrating plant and the shipment of cobbed ore. The North America Mining Company, which owns several claims in this region, is as yet only in the early prospecting stage. Some veins of good ore have been uncovered but the depth reached is not sufficient to get below the oxidation zone.

There are certainly a great many veins hidden under the thick mantle of moss and vegetable debris covering the solid rock. We call prospectors' attention to the opportunity presented by the strip of sedimentary rocks in which the known deposits lie, especially those bordering the masses of igneous rocks, and extending both ways beyond the staked claims in a northeast-southwest direction.

The whole of Gaspesia offers a vast field for prospecting. No systematic work of any kind has as yet been done, and the

rudiments of its geology are barely known. For the moment, the places offering themselves for prospecting are the slopes along the streams, which often show fine natural sections of the rocks. The high mountains in the interior are sometimes quite rugged and their steep sides present bare rocks which can be easily prospected. The layer of moss and vegetable debris is easy to remove and the solid rock is found immediately beneath it, because the rocks are not covered with thick glacial deposits as in the Laurentian plateau and elsewhere; the valley bottoms, alone, are covered with a thin layer of fluvial deposits. In a word, Gaspesia, with its many igneous peaks and batholithic and laccolithic masses, presents a vast field for prospecting in which chances of success are as great, if not greater, than in any other region of the province of Quebec. The history of the projected township of Lemieux—which has, in two years, been transformed from a wilderness into an active and comparatively rich mining centre—may be repeated for other parts of the peninsula.

DISCUSSION

MR. JOHN A. DRESSER: What does the ore from this region assay?

MR. MAILHIOT: It carries about 8 per cent zinc and 4 per cent lead, and averages two dollars a ton in gold.

GRAPHITE IN QUEBEC AND ALABAMA, A COMPARISON

By H. P. H. Brumell

Graphite is pure mineral carbon, of which diamond is the highest and purest form. It is a soft, unctuous substance, black to steel-grey in colour, according to its form, and occurs in both amorphous and crypto-crystalline form. It is one of the most widely distributed of minerals and is known under different names according to locality; thus the mineral is spoken of as graphite in the United States, as plumbago in the British Empire, and as blacklead in Germany and Austria. In the United States the term blacklead is often used when applied to the amorphous form, while the usual term in the trade for the crystalline variety is 'flake graphite.'

Amorphous graphite is almost universal in its distribution, and is usually the result of the alteration *in situ* of coal or other carbonaceous matter. It is usually very impure, the impurities consisting of clay or shale or some other silicate, and it rarely exceeds 70 per cent in carbon, while in the majority of cases it assays below 40 per cent.

Crystalline or flake graphite is very restricted in its distribution and consists usually of elemental or inorganic carbon, and when entirely separated from gangue, or associated minerals, should assay 100 per cent carbon, any variation from this percentage being caused by mechanical impurities only. Some graphite from Ceylon has assayed as high as 99.856 per cent, though the greater bulk of the material from this source does not assay higher than 90 per cent.

Outside of North America the occurrences of flake graphite are not numerous, the only ones of importance being in the islands of Ceylon and Madagascar, from both of which considerable quantities are exported. The deposits in Madagascar are of recent discovery, while those of Ceylon have been operated since about 1825. The ore of Madagascar is a disseminated one similar to that of all the operated flake deposits in North America,

while that of Ceylon occurs in veins of great purity, the ore being shipped crude after a hand sorting into the various grades of lump, chip, dust, and flying dust, in which forms it reaches the consumers, who then have to mill it for the various uses to which it is to be put. The Madagascar ore requires concentration, the graphite content being in the neighbourhood of 10 per cent. The purity of the finished product is solely a matter of mechanical control in its preparation for the market, which question will be discussed later.

The graphite industry in North America probably owes its birth to the late Joseph Dixon who, in 1827, began operations at North Adams, Mass., afterwards transferring his operations to Ticonderoga, N.Y., with the result that, in 1842, the enterprise known as the Joseph Dixon Crucible Co. was inaugurated. The method of separation adopted was very crude, and comprised the use of stamps and stationary Cornish buddles, the stamps being of the old Cornish pattern, afterwards changed to the Californian type. Most of the mills erected later in the state of New York were built along similar lines, though many improvements have been introduced in recent years.

In 1844 Canadian graphite first attracted attention, the particular deposit being one at Grenville, Que., and in 1851 the first public exhibit of the mineral was made at the London Exhibition of that year, after which spasmodic efforts were made to create an industry. It was not until after 1895, however, when the North American Graphite Co. mill was erected (although operated with indifferent success), that any appreciable progress was made. After 1895 important discoveries were made and operations begun in Pennsylvania and Alabama, and it may be said that, with the exception of the operations of the Joseph Dixon Crucible Co., the inception of the present successful graphite industry on the continent dates from that year.

For the purpose of this paper it is necessary only to consider the crystalline ores of the province of Quebec and those of the state of Alabama, partly to compare their characters and modes of occurrence, but principally to follow the evolution of the present methods of milling. If the sequence of events in

this regard in the province of Quebec be followed it will be found that, until the advent of oil flotation, which was used in graphite milling first in Alabama, the pioneer work for the continent has been done in this province.

Although widely separated both geologically and geographically, there is, petrographically, a great similarity between the graphite ores of Quebec's most important field and those of Alabama. The mineral in both fields is crypto-crystalline or, as it is known in the trade, 'flake,' and occurs usually as a constituent of gneiss or, in places, schist. Regarding the geology of the ores of the Buckingham district Dr. R. W. Ells, ("Bulletin on Graphite," Geological Survey of Canada) says:

> It may be now stated that the valuable deposits of the mineral in this province are practically confined to the crystalline limestones and associated greyish mica-gneiss which form the upper members of the Grenville series, formerly regarded as representing the middle or upper part of the Laurentian system. In these rocks, which are cut by frequent masses of intrusives, including granite, diabase, pyroxene, etc., graphite occurs at many widely separated points. The beneficial effect upon the presence of graphite exerted by the agency of intrusive rocks was evident during the examination of many of these deposits by the writer in 1893, when it was seen that in all the mining areas this feature was conspicuous. In all cases where there were large bodies of disseminated ore in the gneiss or limestone such were usually associated with masses of granite or diorite. From notes furnished me by Mr. H. P. H. Brumell, who was engaged in the graphite industry of the Buckingham district for some years, it is evident the same conditions are seen on the property of the North American Graphite Co. He says of the rocks on lot 28, range VI, Buckingham, "that a series of parallel bands of graphitic gneiss are cut without any throw by a diorite dyke about 50 feet wide which cuts the strata at right angles. To the north of this main dyke is a reticulating system of small diorite eruptions in the neighbourhood of which the beds of ore are materially enriched. Again, about 40 chains to the north of the above, and in the pits near the mill of the company, there occurs an apparent overflow of diorite, beneath which cap the richest ore was found. It may be stated in a general way that where the graphitic gneisses are cut by dykes the percentage of graphite is much higher than elsewhere."

In writing of the province of Quebec, regard is had only to the deposits of Labelle county wherein the three townships of Templeton, Buckingham, and Lochaber are situated in this order from west to east, immediately along the north shore of the Ottawa river. The valley deposits of the river overlie the crystalline rocks for a considerable distance back from the river, and it is near the east boundary of Templeton, in the fourth, fifth and sixth ranges, that the graphitic gneisses first

outcrop. From here they extend in a northeasterly direction into Buckingham in a band included in from the fourth to the eighth ranges. There is then a gradual change in direction, the band traversing the township in a more easterly direction to near its eastern boundary, where the band again turns to the northeast and so through the northwest corner of Lochaber township into the township of Mulgrave, where it is cut off by a large granitic mass. With the exception of isolated masses of gabbro and other eruptive rocks having graphitic zones or carrying included graphite-bearing masses, the rocks of the band consist of gneisses and, to a small extent, limestones, the latter in the form of lenses and rarely of great extent. The entire system is cut by numerous dykes of gabbro, diorite, and pegmatite, and it is in the neighbourhood of the greatest eruptive disturbance that there is found the greatest enrichment of graphite.

The graphite field of Alabama was, until quite recently, considered to be pre-Cambrian, but later investigations have demonstrated that it is of Carboniferous age, though the rocks are highly metamorphosed and consist entirely of quartz schists. The following description of the field is from an article published by Dr. W. F. Prouty, Geological Survey of Alabama, in the Birmingham *Age-Herald*, Jan. 28th, 1917:

> The rock in which the flake graphite beds occur is a mica schist, generally considered of pre-Cambrian age, for the most part highly metamorphosed and much intruded by both acid and basic igneous rocks, which are for the most part in long dykes, nearly parallel with the trend of the graphite ore bodies, but in some cases cutting them at small angles. Some of the pegmatite dykes have excellent commercial mica and kaolin. Bordering this mica schist on the west, for the entire length of the area, occurs a green-coloured schist, originally a basic igneous rock, and designated by the Alabama Geological Survey the Hillabee schist. The graphite area is seldom more than three miles distant from this metamorphosed basic igneous mass, and locally is in contact with it. The gap in the graphitic area between Millerville and Goodwater is in part due to the extension of the above-mentioned igneous mass into this portion of the field and the cutting out of the mica schist. The effect of these igneous masses on the associated rocks is in some cases very marked. Secondary minerals of the nature of garnets are often very common bordering the basic intrusions, while muscovite mica occurs frequently in much larger amounts on the border of the granite intrusions.

In comparing the foregoing brief descriptions of the two fields and the graphite deposits therein, it will be noted that in

Quebec there is an enrichment in graphite of the beds at, or near, the contact with the eruptives, while in Alabama there is an increase of muscovite without any appreciable change in the graphite content. The gangue, in Alabama, consists entirely of a very friable quartz, with a small quantity of 'a white fibrous mineral, probably sillimanite,' and occasionally mica, either biotite or muscovite, cyanite, and tourmaline. The gangue of most of the ores of the Buckingham district consists only in part of quartz, the other common minerals being orthoclase, pyroxene, hornblende, sillimanite, and occasionally mica (usually biotite), zircon, tourmaline, chondrodite, and pyrite.

The ore at present mined in Alabama consists almost entirely of the weathered portion of the beds, the weathering usually extending down to the water level in the valleys between the hills on which, almost without exception, the deposits are found, the valley bottoms being usually filled with soil washed down with other detrital matter from the higher ground. This weathered ore is very soft, in most instances breaking down on quarrying like sand, and the whole is easily milled, the quartz being very friable. In contradistinction to the foregoing, the ores of Buckingham are usually hard and tough, except for a very small amount of weathered material at the surface. The quartz in many instances, more especially when forming part of a gabbro which at times constitutes the gangue, is almost carnelian and very hard, while the hornblende tends to toughen the ore. In consequence of this hardness, greater difficulty in crushing and milling is found in Buckingham than in Alabama, and greater care in operation is necessary to obviate the breaking down of the softer mineral. The Buckingham graphite is a larger and heavier flake than that of Alabama, and it is probably due to this superiority in weight for bulk that it is more in favour with the crucible manufacturers and has usually commanded a higher price.

Until very recently, most of the research work in connection with the refining of the mineral on this Continent was done in the province of Quebec, where, until the advent of the oil-flota-

tion method, the highest degree of extraction had been obtained, the most successful plants being those using an entirely dry method, concentration being made by means of pneumatic tables. To follow the evolution of the industry in the Province, it is only necessary to briefly describe the various methods used by the North American Graphite Co., the Anglo-Canadian Graphite Syndicate, the Buckingham Graphite Co., the Dominion Graphite Co., and Plumbago Syndicate, all the work of these companies being done on three mills owned or operated by them in the order named. The original North American mill was equipped with crusher, stamps, buddles, dryer, buhr-stones, and reels. The ore was stamped wet, the pulp passing through a 20-mesh screen on the mortar to a stationary buddle equipped with sweeps. The pulp settled out from the centre post, on which was the feed pan with attached sweeps, the outer zone in the buddle consisting of concentrate assaying about 35 per cent pure. Inside this was a second zone of middling, while the central zone consisted of tailing. All the material was removed from the buddles by hand, the concentrate going to the dryer, the middling to be rebuddled three or four times, and the tailing to the dump. A flat iron pan built over several fire-boxes was used as a dryer. The dried concentrate, without any further manipulation, was then sent to the buhr-stones and subsequent dusting and grading reels. The finished stocks were of high grade, assaying: coarse flake (GR) 92 per cent to 95 per cent, fine flake (GE) 90 per cent to 92 per cent, dust (P12) 60 per cent to 72 per cent. This method was very crude, and only about 30 per cent of the graphite content was saved. In 1901 the Brumell hydraulic separator was patented and introduced, and by means of this machine the mineral was concentrated when dry upon the moving surface of a body of water. This concentrator is probably the pioneer of all flotation machines, and its operation has, very properly, been styled 'skin-flotation.' Concentration is made on this machine by reason of surface tension, the dried graphite floating when distributed upon the moving surface of the water, while the gangue minerals are wet by the water and sink. This machine was immediately adopted by the operators in Alabama and is still in use in many of the

mills there. A concentrate assaying about 55 per cent was obtained, while an extraction of about 50 per cent of the graphite content of the ore was made. The next improvement of note, in the province of Quebec, was the introduction of the Hooper pneumatic concentrator, the first successful pneumatic machine on the market. This machine is so constructed that rapid pulsations of air are forced through a porous cloth, usually broadcloth, which covers the deck of the machine. The dry ore, previously classified and not exceeding 20-mesh in size, is fed to the upper end of the deck, where, by reason of the rapid pulsations of air, the different minerals are classified according to their gravity. The lighter mineral, graphite, is drawn to one side by skimmers set at the necessary height, while the heavier gangue is drawn to the other by riffles and so discharged, both concentrate and tailing being delivered over the apron of the machine; middling is returned for further treatment. With the adoption of this machine it was, of course, necessary to dry the crude ore, and this was done before crushing and rolling, to obviate as much as possible the loss of the freed graphite in the unavoidable drafts that any open, or direct- flame, mechanical dryer necessarily makes. When the Hooper machines were introduced it was found necessary to classify very closely, and this was done by means of the so-called Brumell barrel machine (which was used as a deduster), and Columbian screens. The tailing from the Hooper machines was then fed over Brumell separators, and a very marked improvement in the total recovery was noted. The concentrate assayed about 60 per cent, while the recovery reached about 70 per cent. This method was used at the mills of the Anglo-Canadian Graphite Syndicate, successors to the North American Graphite Co., and the Buckingham Graphite Co.

In 1908, at the mill of the Buckingham Graphite Co., were introduced the Sutton, Steele & Steele dry concentrating tables, when the mill was made an all-dry one and much better results obtained. In addition to the tables there were installed smooth polishing rolls, first introduced shortly before this by Mr. Geo. N. Brewer at the Globe Refining Works at Port Elmsley, Ont., through which the concentrate finer than 70-mesh

was put, the result being that all concentrate averaged, during a period of twelve months, 79.2 per cent, with a recovery of about 78 per cent. In 1910 the old mill of the Anglo-Canadian Graphite Syndicate was taken over and remodelled, the new scheme of separation being a series of smooth polishing rolls with screens of increasing fineness, the intention being to so roll as to crack the gangue particles and scalp off the uninjured flake. The ore at this particular mine at that time was soft and very considerably weathered, and while this condition lasted the recovery of merchantable graphite was fair, being about 75 per cent. With the exception of the dielectric separator the flow-sheet was the same as that of the Peerless mill (Figure 2). The foregoing method was afterwards adopted when, in 1911, the Dominion Graphite Co. mill was built, where it was found to be not quite so successful, the recovery of merchantable graphite falling to 67 per cent.

In 1915 the mill of the Dominion Graphite Co. was taken over by Plumbago Syndicate and a complete dry table plant installed, consisting of screenless sizer and tables according to flow-sheet, Figure 1. As the result of operations here a recovery of merchantable graphite of 85 per cent was made, the average graphite content of all grades being 63.7 per cent, as follows: GR (coarse flake) 91.3 per cent, GE (fine flake) 70.0 per cent, P12 (dust) 46.0 per cent; while the grades were obtained in the following proportions: GR 35.5 per cent of the whole output, GE 21.3 per cent, P12 43.2 per cent.

The term 'merchantable graphite' is used to describe the finished product as it goes to the market, and does not consist of pure graphite, but of finished products assaying in purity from 40 per cent, for low-grade, to any percentage possible over 90 per cent; thus a recovery of merchantable graphite is often made of more than there is graphite contained in the ore. As an instance, one of the plants in Alabama operating on an ore assaying 3.26 per cent has a tailing loss of 0.21 per cent, with a consequent recovery of actual graphite of 3.05 per cent, whereas the merchantable products, assaying about 90 per cent, 80 per

cent and 60 per cent pure, actually represent 3.29 per cent of the ore treated.

Outside of the Buckingham Graphite Co. and Plumbago Syndicate there are two plants in the district of Buckingham which were operating under different systems to those described. They are the Peerless Graphite Co. mill, equipped similarly to that of the late Dominion Graphite Co. with the addition of the Sutton, Steele & Steele Dielectric Separator, which was installed for the elimination of the mica with which the ore is somewhat heavily charged. The flow of this mill is shown in Figure 2. The second plant is that of the Quebec Graphite Co., which is wet throughout, the flow being as shown in Figure 3.

In Alabama, until within the past two years, practically all the mills were equipped with dried ore flotation machines known locally as the 'Ashland washer,' a machine exactly similar to the Brumell Hydraulic Separator, the flow of the mills being, with but slight variation, according to Figure 4. These plants did not make a high recovery, rarely over 50 per cent and usually about 35 per cent. In criticizing this old type of mill particular attention is drawn to the muller-pan, for the use of which there does not appear to the writer any reason other than that given him several times, 'the custom of the country.' The muller-pan is that type of Chilean mill, chaser mill or arastra, used by shale brick makers in the grinding of their shale, and has a most destructive effect on the flake contained in the graphite ore. After the ore passes the muller-pan it is dried in a direct-heat dryer, the result being that a large percentage of the freed graphite, particularly the dust and finer sized flake, is carried off with the smoke and hot gases and is consequently lost. At one mill, in Clay county, the writer learned that the ore averaged 3 per cent of graphite, the wet tailing (practically the only tailing from the mill) assayed about 1 per cent, and the graphite in the marketed products accounted for only 1 per cent, thus showing a loss of 1 per cent, or one-third of the graphite content of the ore, which could only be accounted for as having been lost at the dryer. At some of the best-equipped mills of the Ashland type, an air machine

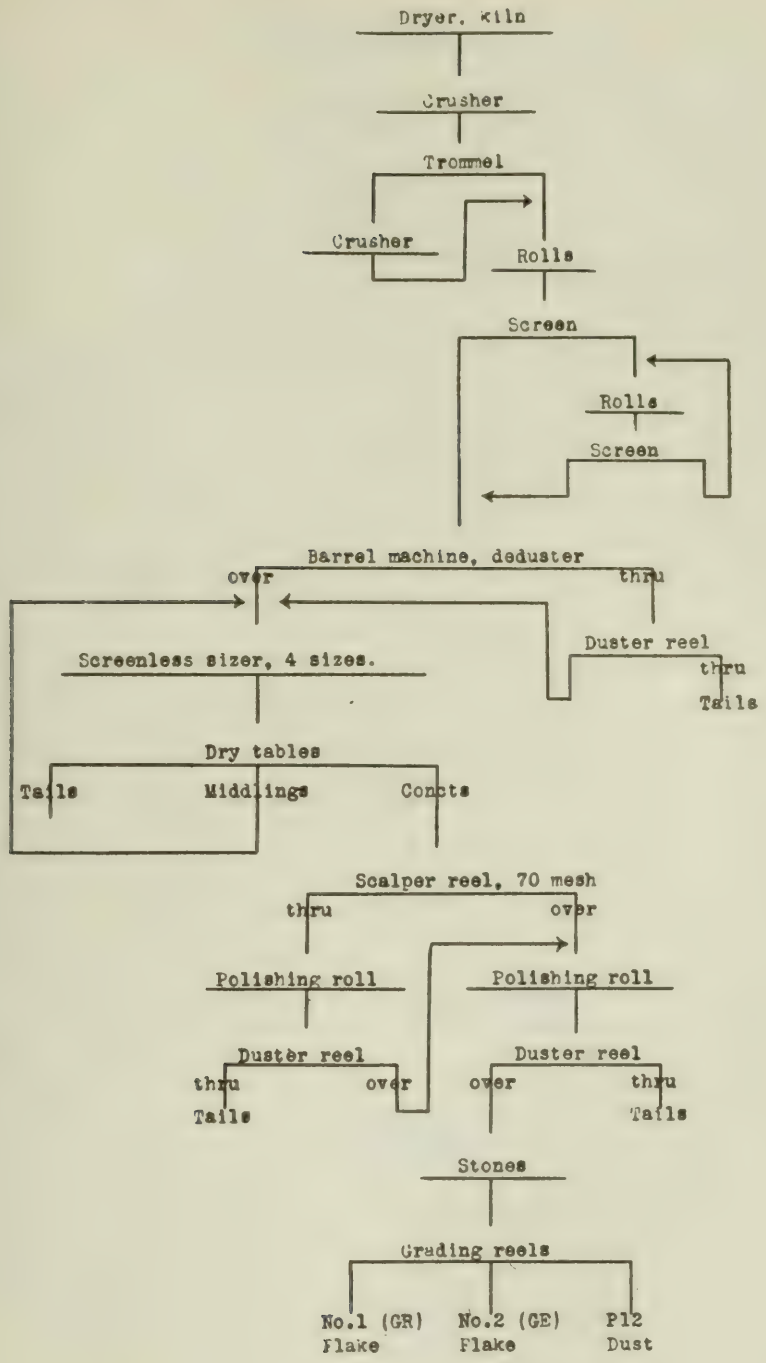


Fig. 1—Flow-sheet of mill using pneumatic table concentrators: Plumbago Syndicate, Buckingham, Que.

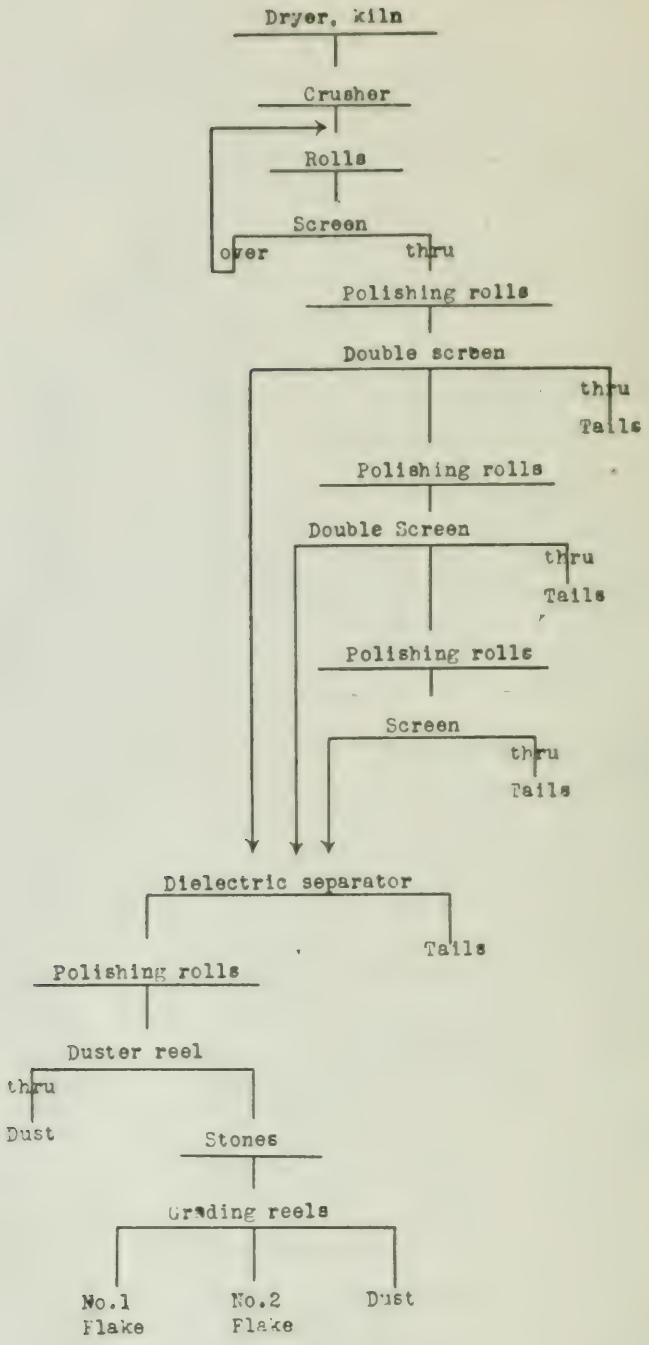


Fig. 2—Flow-sheet of mill using rolls and screens for concentration: Peerless Graphite Co., Buckingham, Que.

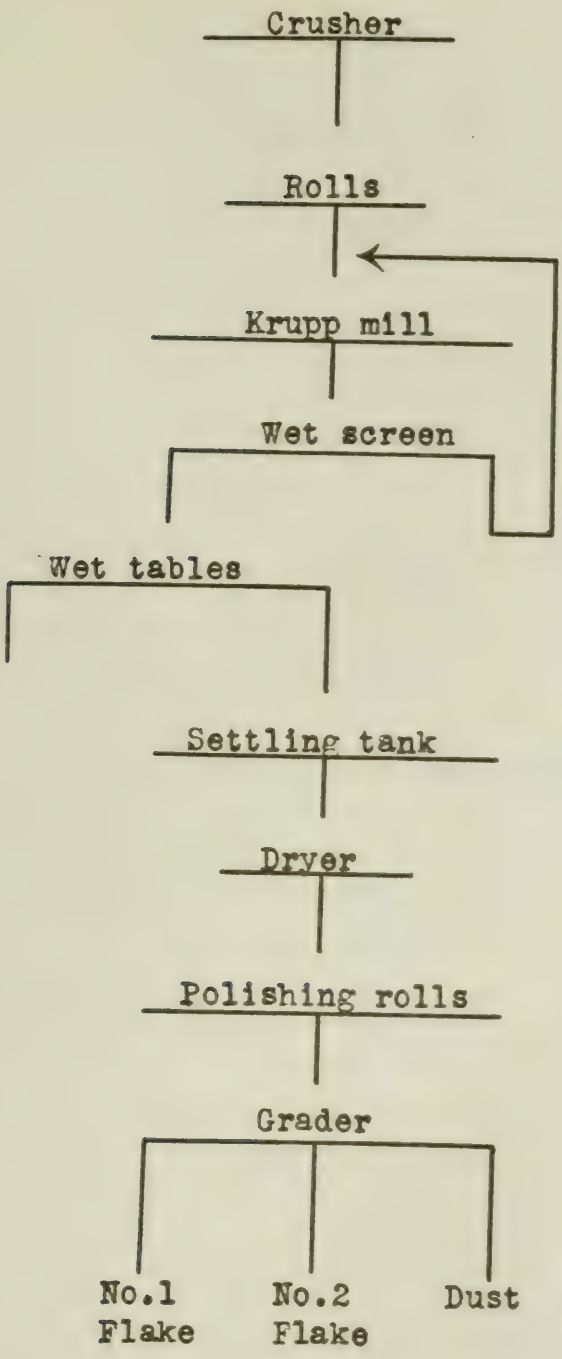


Fig. 3—Flow-sheet of mill using wet table concentrators: Quebec Graphite Co., Buckingham, Que.

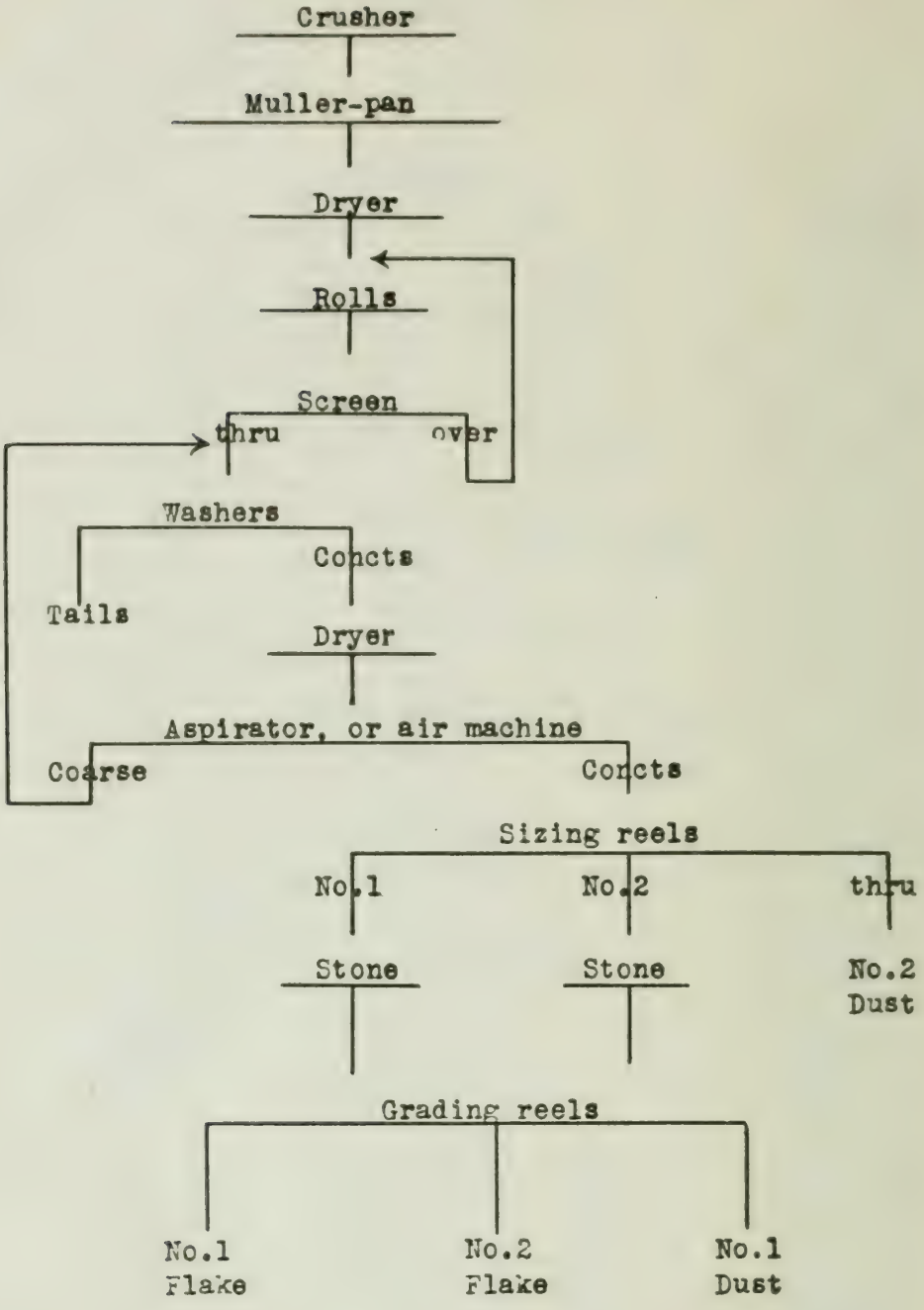


Fig. 4—Flow-sheet of mill using the so-called Ashland process: Clay County, Ala.

is introduced before the washers which classifies the dried crushed ore into dust, fines, and coarse. The dust is screened over a fine mesh cloth and a considerable flake concentrate is obtained; the fine-sized ore goes to the washers and the coarse either to the dump or back to the rolls as its quality indicates. Concentrate from the washers assays all the way from 40 per cent to 70 per cent and is further treated with air, the usual method being, as described by Mr. Geo. D. Dub, "Preparation of Crucible Graphite," U.S. Bureau of Mines, 1918, as follows:

> Air classification is used in most refining plants and forms an important step in the refining process. Such apparatus is usually home-made. So far as is known, no experimental work has been done by the large majority of operators with a view to determining the most efficient proportions and shape for this device. In principle, an air suction created by a fan at the back end of each chamber is applied to a falling stream of graphite ore or concentrate. The heavier material, which is made up of quartz grains with attached graphite, is practically unaffected by the air suction, and falls into a hopper furthest from the fan. The lightest particles are drawn closest to the fan, which draws the finest dust into the atmosphere. When this apparatus is used on crude concentrates, the middlings—which include the heaviest flake—form No. 1 flake stock, going to the No. 1 buhr mills, while the finer material closest to the fan is screened to remove as much finished No. 1 flake as possible.

After the above treatment in air the concentrate is finished in the usual manner by means of buhr stones and screens.

Prior to 1917 there were, in addition to those mills using the Ashland method, one wherein concentration was made by the Huff Electrostatic machine and one wherein the Minerals Separation method of oil flotation was used. Regarding the mill equipped with the Huff machines but little may be written, as, up to the date of writing, it is the only plant of its kind, and as it has proved highly profitable the owners are not over-anxious to discuss the method. It may, however, be stated in a general way that crushing and rolling are had in the usual manner, the ore being dried between the crusher and the rolls by means of a direct-heat revolving dryer. A rough concentration is first made by a system of air classifiers and screens, the concentrate so obtained being then treated on a modified Huff (or new type) electrostatic machine, after which, with no treatment other than dusting and grading, the products are ready for the

market. The No. 1 stock produced at this mill is said to assay, uniformly, 90 per cent pure.

Since 1917, and with the advent of the oil flotation method of concentration, the industry in Alabama has made wonderful progress, and this method would seem to have solved the problem of cheap extraction. In the past two years many new mills have been erected and a few of them operated successfully, the most successful being those wherein flotation methods were employed. The following is a list of the plants in the three counties of Clay, Coosa and Chilton, and their condition in April, 1919:

Name of Company	*County*	*System*	*Condition*
Liberty Graphite Co	Clay	Callow	Idle
Lineville Graphite Co	"	Ashland	"
Carbon Mountain Graphite Co.	"	Callow	Operating
Peerless Graphite Co	"	Ashland	Idle
Jennings Graphite Co	"	"	"
Republic Graphite Co	"	"	"
Crystalline Flake Graphite Co.	"	Log washer	Operating
Clay County Graphite Co	"	Ashland	Idle
Monitor Graphite Co	"	Callow	"
Cahaba Graphite Co	"	Ashland	"
Graphite Mills, Inc	"	Dry tables	Operating
National Graphite Co	"	Ashland	Idle
Southern Graphite Co	"	Callow	"
Acme Graphite Co	"	Log Washer	Remodelling
Ashland Graphite Co	"	Callow	Idle
Griesemer Graphite Co	"	Wet tables	Rebuilding
May Brothers Graphite Co	"	Ashland	Operating
Alabama Graphite Co	"	"	Idle
do No. 2	"	Log washer	"
Axton-Noe Graphite Co	"	Ashland	"
American Graphite Co	"	Mineral Sep'n	Operating
Quenelda Graphite Co	"	Ashland	Idle
Norway Graphite Co	"	?	"
Eagle Graphite Co	"	Log washer	Rebuilding
C. B. Allen Graphite Co	"	Callow	Operating
Jefferson Graphite Co	"	"	"
Atlas Graphite Co	"	"	"
Superior Flake Graphite Co	"	Brown flotation	"
Crucible Flake Graphite Co	"	Ashland and Mineral Sep'n	"
Hood-Graves Graphite Co	"	Ashland	Idle
Graphite Company of America	Coosa	Electrostatic	Remodelling
Goodwater Graphite Co	"	Ashland	Idle
The Ceylon Co	"	Mineral Sep'n	Operating
Parkdale Graphite Co	"	Simplex	"
Diamond Graphite Co	"	"	Remodelling
Seminole Graphite Co	"	Callow	Operating
Duro Flake Graphite Co	"	Simplex	Idle
Flaketown Graphite Co	Chilton	Electrostatic	Operating

As "comparisons are odious" it is not thought advisable to describe any individual plant, but rather to give a brief description of the methods used and a general idea of the mills equipped under the different systems. As will be seen on reference to the foregoing list, there are 38 mills in the State, the equipment as to concentration being divided as follows:

*Ashland type	Skin flotation	14½
Callow type	Oil flotation	9
*Minerals Separation type	do	2½
Simplex type	do	3
Brown type	do	1
Wet concentrating tables		1
Dry concentrating tables		1
Log washer type		4
Electrostatic machines		2

*One mill equipped with both Ashland and Minerals Separation machines.

Of the sixteen oil flotation plants in the district nine are equipped with Callow cells, and it is understood that several mills are soon to be changed from the Ashland to this type, which has apparently given satisfaction. A typical lay-out of the Callow type mills is shown in the accompanying flow-sheet, Figure 5. The flow-sheet is a composite of all the mills in the district. At some the ball mill is replaced by rolls, while others have not installed the wet tables, but rely upon an air treatment of the concentrate before finishing. At one of the best-equipped mills the concentrate, which assays about 55 per cent, is split over dewatering screens of 100-mesh, the oversize going to Wilfley tables where they are enriched to over 85 per cent, and the throughs going to a recleaning cell whence all concentrate is delivered to the finishing plant at about 82 per cent. The flow-sheet of the Minerals Separation system, Figure 6, is self-explanatory, as is that of the Simplex, Figure 7. The flow-sheet of the mill using dry concentrating tables, Figure 8, requires but little explanation. The ore, after reduction to 20-mesh, is run through dedusters, by means of which all the fine dust and the fine freed graphite are drawn off, the coarser material going to a 40-mesh screen, the product of which goes to a second deduster wherein the suction is considerably stronger, the result being an extraction of a coarser-sized graphite,

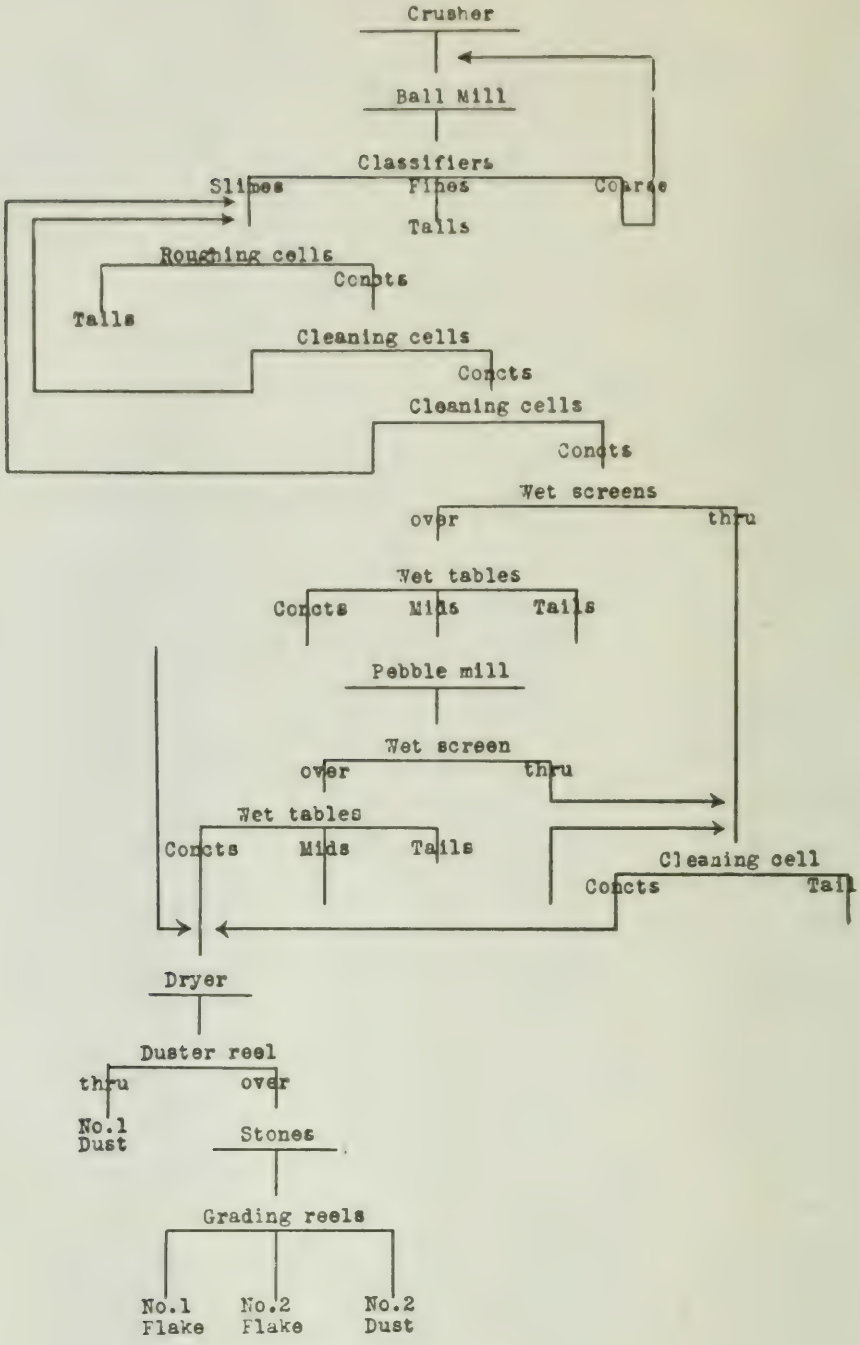


Fig. 5—Flow-sheet of mill using Callow method of concentration: Clay County, Ala.

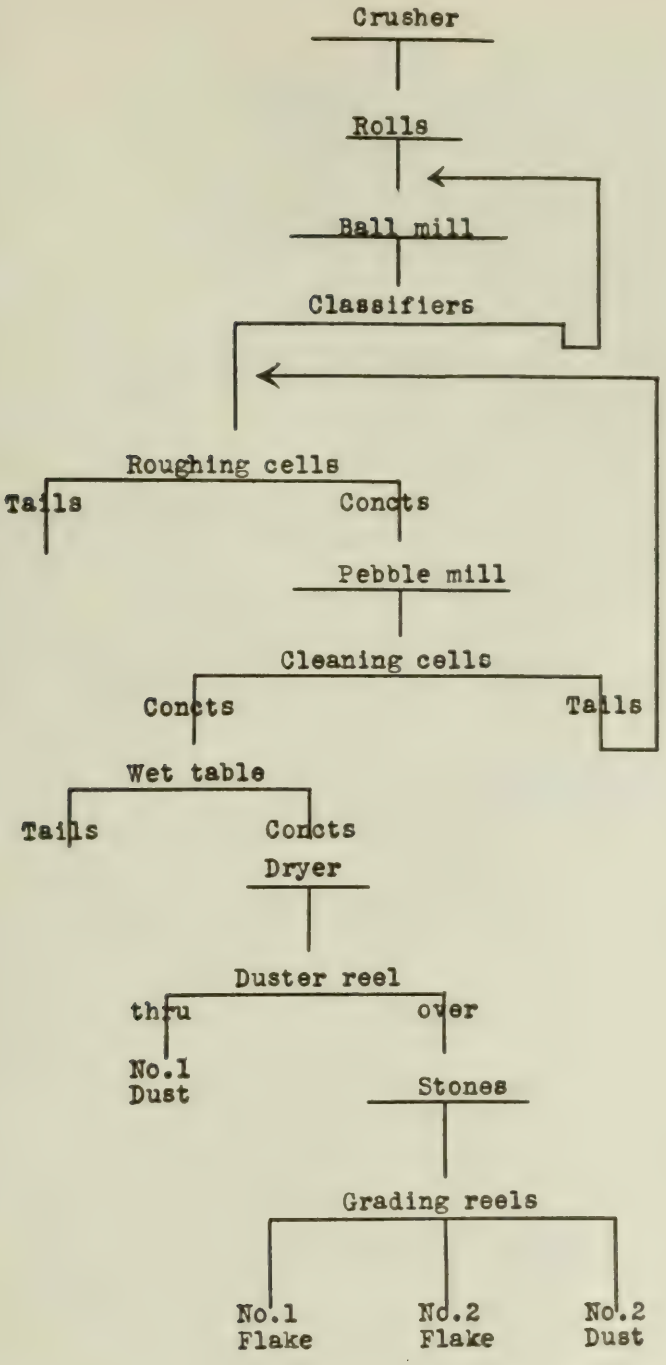


Fig. 6—Flow-sheet of mill using Minerals Separation method of concentration: Ala.

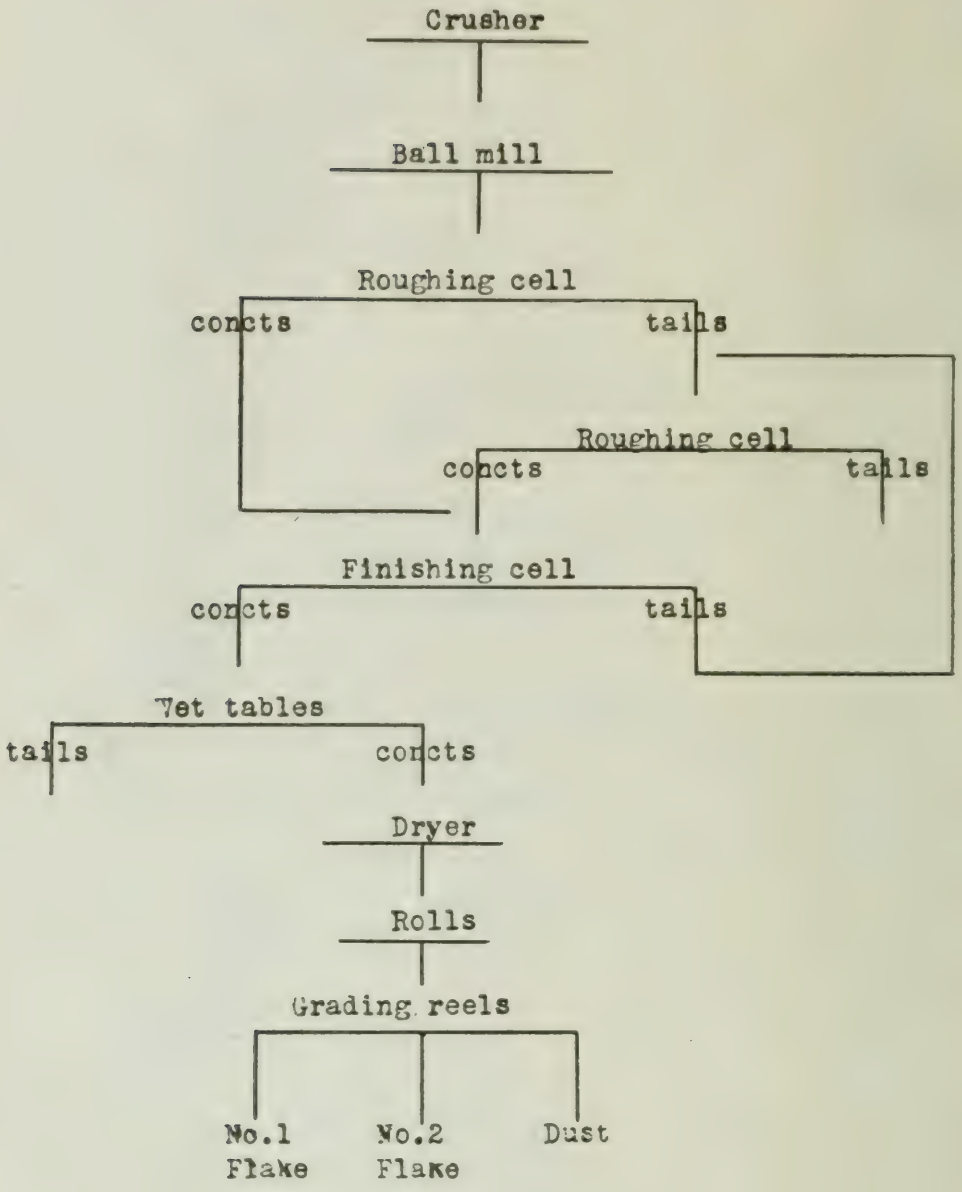


Fig. 7—Flow-sheet of mill using Simplex method of concentration: Coosa County, Ala.

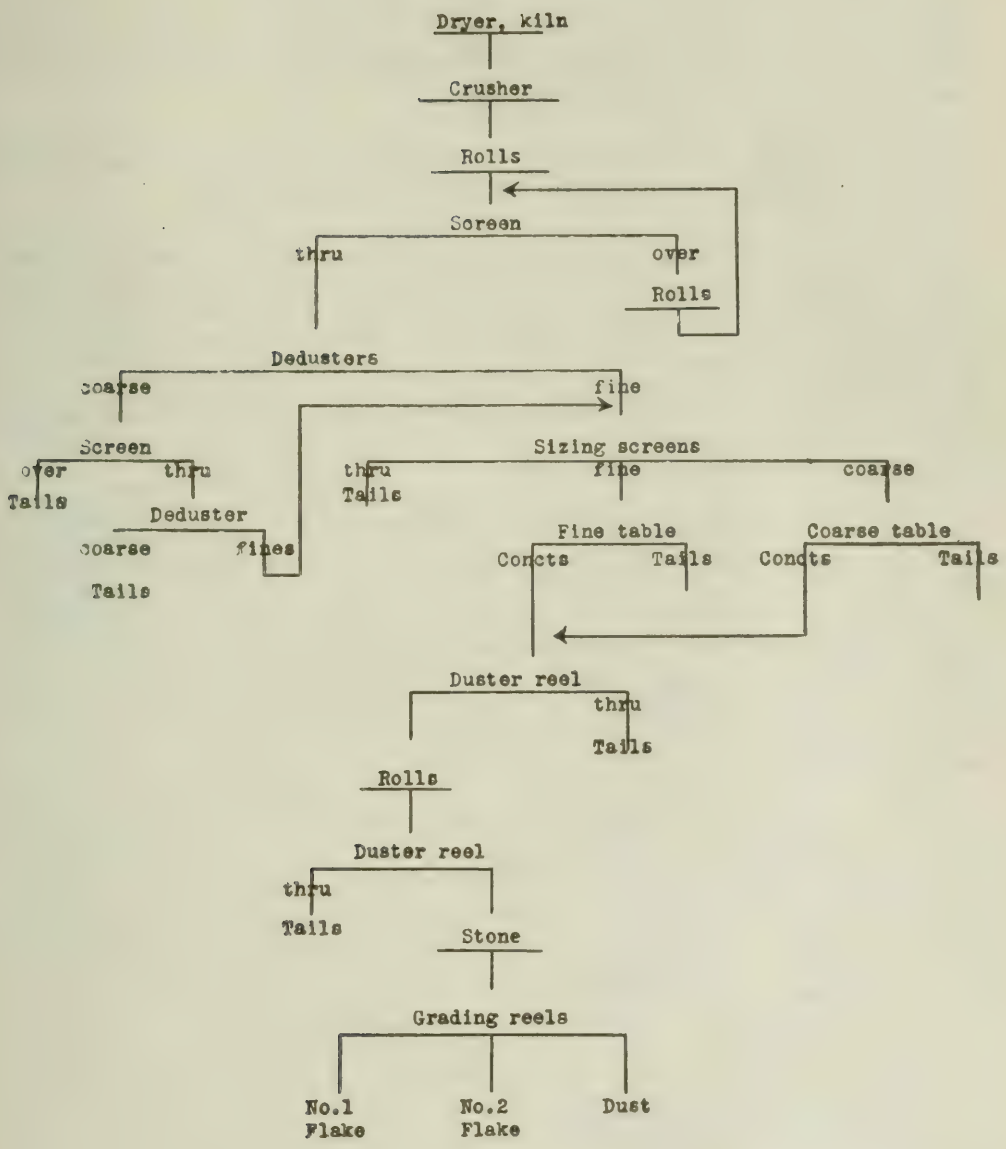


Fig. 8—Flow-sheet of mill using Pneumatic Table concentrators: Clay County, Ala.

with a certain proportion of fine-sized sand. The product of both these dedusters is screened over 100-mesh, the throughs, or dust, going to waste, while the oversize is classified as to size and delivered to Sutton, Steele & Steele dry concentrating tables where concentration is made. The concentrate at this mill is treated on smooth polishing rolls before going to the stones for final treatment in the finishing plant.

Regarding the log-washer method, Figure 9, Mr. Geo. D. Dub, "Preparation of Crucible Graphite," says:

> In this method of treatment the crude ore is washed and screened without drying. It is then treated in log washers, kerosene oil being added to the water in the apparatus. The concentrates are screened, washed on a cement floor, drained and dried. This system eliminates the expensive preliminary drying of the crude ore, necessary with the water 'skin-flotation.' The simplicity and effectiveness of this plant are clear to the observer. The grade of rough concentrate made is excellent and the only loss of any extent occurs in the coarse-sand tailings, which with regrinding might be made to yield considerably more flake graphite.

The Griesemer Graphite Co. are rebuilding one of the largest plants in Alabama, which, before it was partially destroyed by fire, was equipped with Ashland washers. The rebuilt and remodelled mill will rely upon wet classification and tables for concentration. Details have not all been worked out nor are they all known to the writer, so it is not possible to submit a flow-sheet.

The superiority of the oil-flotation method of concentrating graphite having been demonstrated, it is to be presumed that all mills in the future will be equipped with one or other of the various types of machines on the market or by flotation apparatus of home construction. The types so far used in Alabama comprise, Minerals Separation, Callow, Simplex, Brown, and Janney; the latter only, up to the time of writing, for recleaning. In those cases where the machines are followed by wet tables, either Wilfley or Deister, concentrate is being made assaying from 80 per cent to 88 per cent, with an extraction ranging from 83 per cent to 90 per cent. With all the types of machines the extraction is in inverse ratio to the size of the graphite particles in the pulp; thus, the coarser the graphite the poorer the extraction, and the greater the proportion of

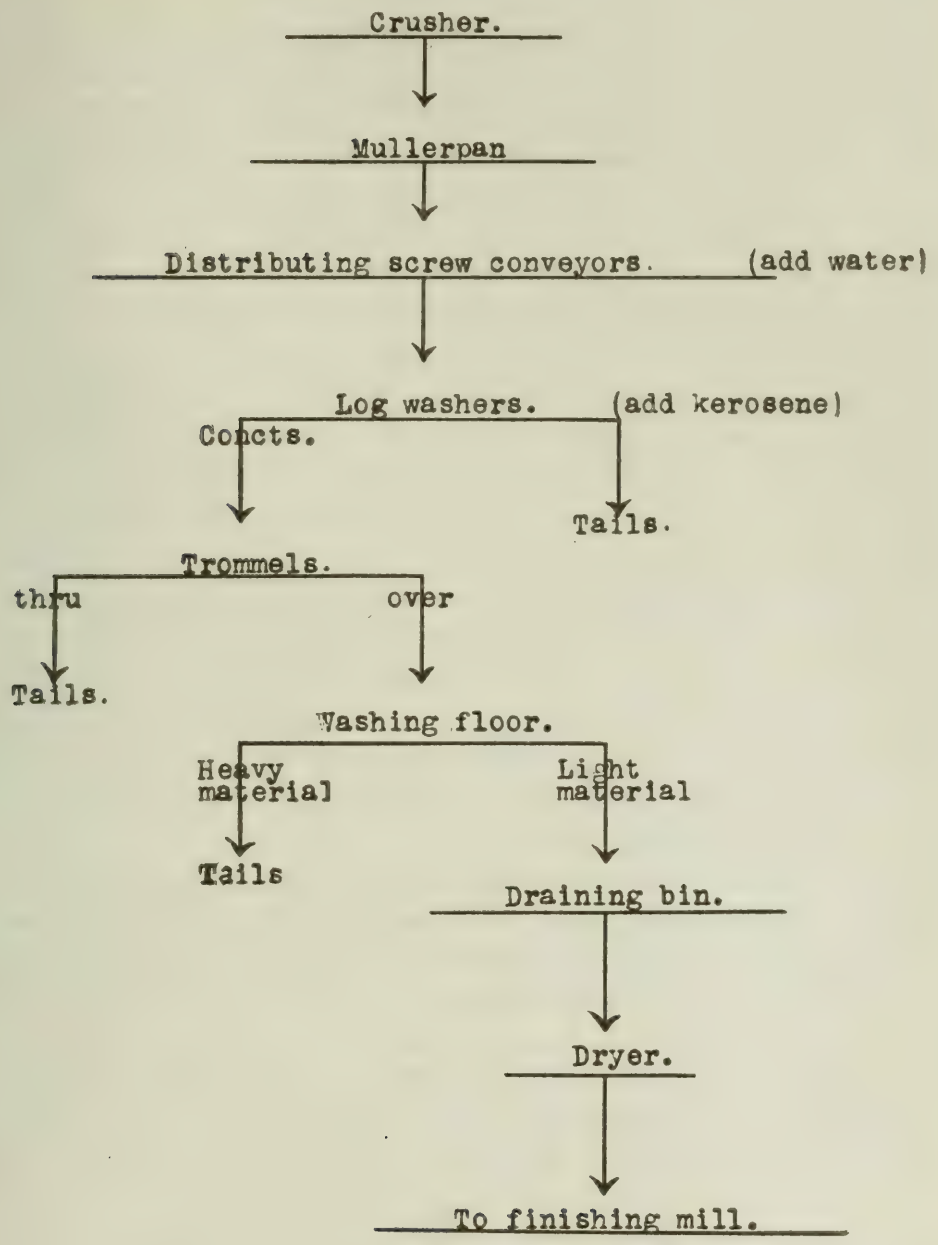


Fig. 9—Flow-sheet of mill using 'Log Washer' type of concentrators.

saving of the coarser material the poorer the concentrate. There is scope here for expert mill practice, and the most successful operator will be he who can best adjust the two conditions. It is not the intention to criticize or compare the methods of mechanical or pneumatic agitation, but, in a general way, it may be positively stated that the machine which affords the greater time for the settling of the froth will give the higher per cent concentrate, whether the froth be made by one or the other method. As an example showing the difference between immediate and delayed discharge, or fresh and settled froth, the writer took samples from a machine using pneumatic agitation, when the fresh froth assayed 44.2 per cent, while that which had been allowed to float for one minute assayed 56.0 per cent. This settled froth condition is only obtained on the Minerals Separation and Brown machines of those used in Alabama. In the matter of the recovery of the coarse flake this question of froth settling is a serious one, as any agitation sufficient to lift the heavier graphite will, perforce, lift considerable gangue, and if quick delivery be made poor concentration will be the result. In the Brown washer, now being tried out in Alabama, it would appear that a strong lift and slow delivery are obtained, and, in consequence, a good concentrate and recovery are made.

In general practice, in Alabama, various crushers are used, both jaw and gyratory, and the crushed ore is, in some instances, further reduced by rolls before going to the ball-mill, to which it is fed after oiling. The emulsification of the water before the ball-mill tends to save all the freed flake, as the revolving and churning action of the mill creates a froth which carries the graphite through, leaving only the coarser particles of ore to be ground. It was feared on the introduction of ball-mills into the district that they would be so destructive of the flake as to be inoperative except for the making of fine flake and dust. Experience has, however, proved that with prior oiling of the pulp and with care in adjustment and operation excellent results can be obtained. The ball-mills in use in the district comprise Marcy, Hardinge, Lehigh, and Marathon types. Various classifiers are in use, including the Dorr, Akins, Gemmell, and

Deister. Hitherto but little attention has been given to the operation of classification, the machines having been used almost solely for the purpose of returning oversize to the ball-mills. It is, however, thought that with proper adjustment a very large proportion of barren material might be removed and full advantage taken of this important operation. With an ore in which the graphite frees easily there is no reason why at least 50 per cent of the gangue should not be eliminated.

After concentration is made the usual methods of refining or finishing are followed, the concentrate after drying going immediately to the finishing plant. In most of the mills some type of air classifier is used, either an aspirator or the apparatus already described, while two of the mills use high-speed smooth flour mill rolls, the action of which is to crack the coarser gangue particles, the consequent dust being removed by screens clothed with silk bolting cloth. At one of the latter mills the concentrate was improved from 71.8 per cent to 85.7 per cent, and in the other from 51.0 per cent to 82.0 per cent. After treatment, as above, the finished concentrate goes direct to the buhr-mills, where it gets a final grinding and polishing, and is then graded for the market, the stocks, in Alabama, being known as No. 1, No. 2, No. 1 dust, and No. 2 dust. It has not been found possible to obtain the proper assays from which to make an average, but it may be stated that the average of No. 1 would be about 88.0 per cent, of No. 2 about 82.0 per cent, and both qualities of dust from 30.0 per cent to 50.0 per cent graphite.

In comparing the graphites of the two fields under consideration, it will be found that they are only mineralogically similar, both being crypto-crystalline and affording what is known to the trade as 'flake graphite.'

Geologically they are wide apart, the ore of Buckingham being of Archæan and that of Alabama of Carboniferous age. Genetically the Buckingham graphite is inorganic, or elemental, while that of Alabama is organic, being the result of the alteration of coaly or carbonaceous material contained in the sedimentary sandstones prior to their metamorphism. In the

matter of graphite content in the ore there is a pronounced divergence, as is evidenced by the following extracts from official reports on the two districts. Geo. D. Dub, "Preparation of Crucible Graphite," United States Bureau of Mines, 1918, says:

> The ore in Alabama averages about 2½ per cent graphitic carbon.

Fritz Cirkel, "Graphite," Mines Branch, Canada, 1907, says :

> The percentage of graphite generally met with in disseminated ores, from which so far the bulk of the Canadian graphite has been extracted, according to figures before the writer, may be put down from 7 to 30 per cent.

There is considerable physical difference between the two products, the Alabama material being of a lower specific gravity. According to F. G. Moses, United States Bureau of Mines, the average specific gravity of Alabama graphite is 2.1; while, according to G. C. Hoffman, Geological Survey of Canada, 1876, that of Buckingham is 2.268; that of Ceylon being 2.259. The Buckingham product is a coarser, bolder, and, by reason of its greater gravity, heavier flake than that of Alabama. This question of weight for bulk is a serious one when considering the matter of crucible stock, and it is largely due to this quality that the product of Ceylon has hitherto been held in such esteem by the crucible makers. From the following list (Fritz Cirkel, "Graphite"), of well-known flake graphites it will be seen that the Buckingham product is, on the score of weight for bulk, preferable to that of Ceylon, while its heat-resisting quality is practically identical, the ratio being as 1.004 for Ceylon to 1.007 for Buckingham, the slight superiority being in favour of Ceylon.

	Specific gravity	Refractory value
Madagascar	2.4085	.....
Cumberland, England	2.3455	.....
Passau, Bavaria	2.3032	.....
Buckingham	2.2685	1.007
Ticonderoga, N.Y.	2.2623	1.007
Ceylon	2.2591	1.004

Complete analyses of the products of the principal United States districts, Buckingham and Ceylon, are as follows. The assay of the Buckingham material is that of GR produced by the Anglo-Canadian Graphite Syndicate, and was made by

A. E. Tucker, Birmingham, England; those of the others were made at the Pittsburgh station of the United States Bureau of Mines. (Geo. D. Dub, "Preparation of Crucible Graphite.")

	Alabama	New York	Pennsylvania	Ceylon	Buckingham
Volatile C	1.89	1.30	1.53	1.68	.....
Graphitic C	87.03	88.97	88.80	85.06	93.87
SiO_2	5.85	4.34	5.24	7.81	3.61
Al_2O_3	4.17	2.40	2.05	2.82	1.33
Fe_2O_3	.38	1.08	1.75	1.61	1.35
TiO_2	.15	.38	.05	.13	.....
CaO	..	.07	..	.19	
MgO	.13	.76	.09	.21	.44
K_2O	.21	.55	.08	.25	
Na_2O	.04	.12	.12	.11	
SO_3	.04	..	.21	.005	.....
P_2O_5	.02	.02	.05	.05	.....
MnO	..	..	.07	.04	.....
ZnO	..	..	..	.03	.....

As the prime object in the mining and refining of flake graphite is the production of crucible stock, it may not be amiss to quote the following as explaining the necessity of the crystalline or flake form of the mineral:

Stingle, *Berliner Berichte*, 1873, says:

For the manufacture of crucibles, besides the determination of the constituents of the ash and the pyrometric qualities, due regard must also be given to the scaly or lamellar structure of the graphite, because it is a well-established fact that such lamellar graphite resists effectively the fire for a longer period than the amorphous varieties; it prevents the cracking of the crucibles, which might be explained by the easy dislocation of the single laminæ or scales, caused by sudden changes in temperature, without disturbing the coherence of the material.

Weinschenk, "*Donath, der Graphit*," 1898, says:

The difference which exists in the quality of crucibles, in the application of a slaty, scaly and in that of an earthy graphite is a very wide one: crucibles made with the latter do not possess the tenth part of resistance possessed by those made with the former. An explanation of the cause of this difference is not difficult to find: the scaly graphite, which is intimately mixed with clay, forms in the latter a more or less coherent skeleton, which imparts to the clay a high degree of solidity. As further, the graphite scales along their planes very easily slip past each other, it is evident that the crucible possesses also a high degree of elasticity, which renders it highly resistant to sudden changes in temperature. In the case of the employment of earthy, amorphous graphite, however, the latter is more evenly mixed with the fire-clay; the single graphite individuals are not in close contact with each other, and the crucible possesses only a small resistance against cracking.

In the matter of the size of particle the Buckingham material may claim a considerable advantage over that of Alabama, as is evidenced by the following comparison of screen tests of coarse flake stocks. The Buckingham stock is GR produced by the late Dominion Graphite Co., while the Alabama stock is the average of three typical mills operating the Ashland, Minerals Separation and Simplex types of washers:

Screen mesh		Buckingham, GR		Alabama, No. 1	
		Separate per cent.	Cumulative per cent.	Separate per cent.	Cumulative per cent.
On	30	4	4	..	..
"	40	16	20	11	11
"	50	18	38	..	..
"	60	30	68	37	48
"	70	27	95	..	..
"	80	3	98	30	78
"	90	2	100	..	..
"	100	..	..	15	93
Through	100	..	..	7	100

The following is the average of screen tests of eight samples of Alabama No. 1 that are "being used in the experimental work of the Columbus, Ohio, Experiment Station of the Bureau of Mines on Graphite Crucibles" (Geo. D. Dub, "Preparation of Crucible Graphite"):

Screen mesh		Separate per cent.	Cumulative per cent.
On	35	6.5	6.5
"	65	45.6	52.1
"	100	38.2	90.3
Through	100	9.7	100

In the report above cited it is recommended that, for the making of crucibles, the finished graphite should be 85 per cent pure and that, in the matter of size, 3 per cent should stand on a 35-mesh cloth, 50 per cent on 65-mesh, and that all should stand on 100-mesh. This specification is doubtless suggested as one that the Alabama field can satisfy. The standard adopted, in succession, by the North American Graphite Co., Anglo-Canadian Graphite Syndicate, Buckingham Graphite Co.,

Dominion Graphite Co., and Plumbago Syndicate with that suggested for Alabama would compare as follows:

	Carbon	On 35	On 65	On 100
Buckingham	90.0%	12	81	100
Alabama	85.0%	3	50	100

In conclusion, it may be stated that Alabama has a field containing very extensive beds with a low graphite content; that Buckingham has much smaller beds with a high graphite content. The Buckingham ore produces much the better crucible stock by reason of its greater weight for bulk and size of particle. In regard to the second grade of flake, No. 2 or GE, there is not much difference, as they are both the result of similar methods of finishing and have their limits of size made by reason of the mesh of the screens used in grading, the size being from 100 to 150. In the material finer than 150-mesh there is a very considerable difference, the dust of Alabama, except when very high-grade, being light coloured by reason of the gangue, which is usually yellow or reddish, while that of Buckingham is very dark by reason of the hornblende and pyroxene, and the consequent dust is almost black. It has always been possible to sell Buckingham dust (P12) to much greater advantage than that of Alabama; in point of fact, P12 has always found a very ready market when assaying anything higher than 40 per cent of graphite. Alabama dust of this carbon content is almost unsaleable.

It may be stated in closing that both fields contain all the elements necessary for success;—ore, labour, and shipping facilities—and that the establishment of a permanent industry is solely a matter of proper business organization and management. In neither field is the industry a mining, but rather a milling, problem, and as such will become standardized, as are other industrials.

DEPOSITS OF NATIVE COPPER IN ARCTIC CANADA*

By J. J. O'Neill

(Annual Meeting, Montreal, March, 1919)

The Government of Canada decided in December last to withdraw from staking for minerals, all of Arctic Canada lying north of 65 degrees N. latitude, and between 105 and 116 degrees W. longitude, "in order that the deposits of native copper reported to exist in that region may be thoroughly examined."

The objects of the present paper are threefold:—

(1) To indicate the distribution and general occurrence of the deposits of copper referred to in the Order in Council.

(2) To outline the general character of such an examination, and the conditions which must be met in carrying it out, such as:

Means of access to the deposits.

Amount of time available for actual work, together with the time consumed in travel and enforced idleness.

Climate and general working conditions.

(3) To discuss the advisability of the use of aeroplanes for carrying out the work, and to indicate the most suitable bases from which such a scheme would be feasible.

Historical Notes

It has been known for more than 200 years that native copper is to be found near the north central coast of Arctic Canada. Samuel Hearne was the first white man to actually visit the deposits when, in 1771, he reached the Coppermine river, in company with some Indians. His observations are of little value except as to the location of the occurrence.

In 1821, Franklin reported that he found native copper along the Coppermine river, and also on the islands of Bathurst inlet; since that time Richardson, Rae, Dease, Simpson, and

* By permission of the Director, Geological Survey of Canada.

Hanbury, have all confirmed both of Franklin's localities, but none of them had sufficient training to enable him to interpret correctly what he saw of these occurrences. Most of these reports were exceedingly optimistic as to the amount and grade of copper ore to be found in those districts.

In 1835, Sir James Ross[1] found trap rocks on the east coast of Boothia in latitude 70 degrees N. and notes copper ore from the Agnew river.

Large masses of native copper are found on the shores of Princess Royal islands, and large quantities of native copper on the shores of Prince of Wales island, according to DeRance[2]; the copper at the first of these localities may have been carried there by the continental glaciers, but that on Prince of Wales island is not so easily accounted for and may not be far from its source.

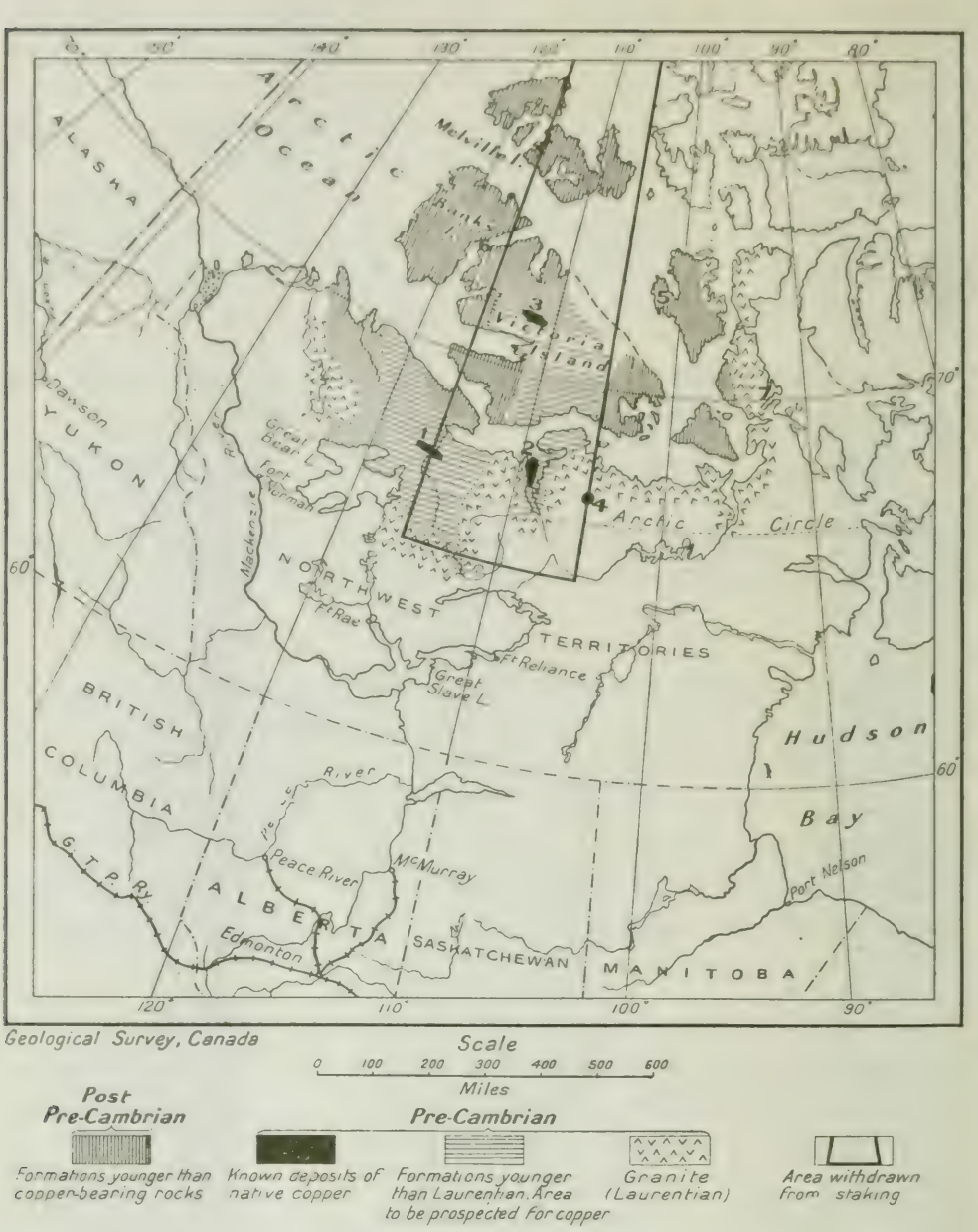
Copper in large masses is said to occur about 40 miles N.E. of the head of Prince Albert sound, Victoria island. This was reported to Mr. Stefansson in 1910 by some Eskimos, and in 1915 many Eskimos testified to the Canadian Arctic Expedition concerning the same occurrence. They produced some of the copper and said that masses, much larger than a man, protrude from the hillside, but whether they occur in solid rock or in drift could not be determined from them.

In 1917, a patrol of the Royal Northwest Mounted Police reported finding native copper in rocks about 60 miles east of Bathurst inlet, as shown on the map. The information from this locality is, like that from the others, very vague.

In summary then, there are two large areas of copper-bearing rocks, i.e., about the Coppermine river and in Bathurst inlet, which were first reported by Indians and Eskimos, and later were visited and their occurrence confirmed by white men. Two other areas of unknown extent have been reported by white

[1] Narrative of Second Voyage in Search of a N. W. Passage, by Sir James Ross, 1835.

[2] De Rance—*Nature*, Vol. XI, p. 492.



men, one on Boothia peninsula, and one east of Bathurst inlet. Eskimos report that there are deposits of native copper in central Victoria island, on the Princess Royal islands, and on Prince of Wales island. The first and last of these reported occurrences seem worthy of some investigation.

Definite information has been obtained concerning the Coppermine river deposits by a party sent there in 1911 by the late Dr. James Douglas; the results of this investigation were presented at the Annual Meeting of the Canadian Mining Institute in 1913 in a paper by Dr. Douglas. The Bathurst inlet deposits were examined and mapped by the writer, in 1915 and 1916, while a member of the Canadian Arctic Expedition, and a summary of his results is printed in the Bulletin of the Canadian Mining Institute for March, 1917. Both these investigations were in the nature of reconnaissances, but a review of the data obtained will enable one to form some idea of the possibilities of the region.

THE COPPERMINE RIVER DEPOSITS

These deposits are found in a series of superimposed flows of basaltic lava, with occasional interbedded conglomerates or sandstones, which occupy a belt 16 miles in width, and more than 40 miles in length. This belt is known as the Copper mountains; it crosses the Coppermine river about 40 miles from the mouth and runs in a direction a little north of west. The flows and sediments dip towards the north at about 12 degrees, so that only the edges are exposed, the remainder passing under younger rocks to the north.

The Indians report finding copper in these mountains for 40 miles to the west of the Coppermine river, and Hearne's locality was about 25 miles east of the river. The deposits do not connect directly with those of Bathurst inlet, as was formerly thought, nor do they seem to swing out to the coast of Coronation gulf, so it is probable that they are entirely covered by younger formations somewhere within 75 miles to the east of the Coppermine where they are cut off completely by the Laurentian granites.

Dr. Douglas' party reported that they found native copper in place at Copper creek in an exposure of 30 feet of basalt. The copper was in amygdules and as tiny shots or flakes in the massive portion of the rock. At Burnt creek they found copper similarly distributed through a total of 51 feet of basalt, and in

pebbles in 25 feet of conglomerate. The assays ran from a trace up to 0.25 per cent of copper in the massive rock, and up to 7.7 per cent in the amygdaloidal portion. Copper stain was seen in many flows. Just north of the Copper mountains the Eskimos find plates and masses of copper in large quantities in the drift. Dr. Douglas considered that the information brought back by his party, although they only spent about one month in actual prospecting, was sufficient to warrant further extensive prospecting in that region.

Bathurst Inlet Deposits

Deposits of Native Copper.—The copper-bearing rocks in Bathurst inlet are apparently distinct from those about the Coppermine river. They occupy an oval-shaped area which extends about 50 miles N.W.-S.E. and has a maximum width of about 25 miles. This area includes more than 150 islands ranging in size from a few hundred square yards to several square miles, also part of the western mainland, i.e., Bank's peninsula, and a strip along the coast five or six miles broad extending from Arctic sound to Moore bay.

The formation consists of a series of basic lava flows with a few thin beds of sediments. They are the youngest rocks in this region, and are exposed everywhere at the surface. As there is very little overburden of soil or drift, prospecting would be a very easy matter. The beds dip at about 6 degrees so that they form a shallow basin, or basins in the area.

Native copper was seen on practically every island in this area as well as on the mainland. The distribution of the metal is remarkably uniform in the same flow wherever found. For instance one flow, which was about 75 feet in thickness, showed tiny shots or flakes of copper all through the groundmass; it was traced for more than two miles along Bank's peninsula and the copper content was apparently the same everywhere.

The native copper occurs in three forms:—

(1) As disseminated copper; minute flakes scattered throughout the dense groundmass of the basalts.

(2) As amygdaloidal copper; irregular grains and small masses filling, or partly filling, the branching gas-cavities near the surface of the basalts.

(3) As vein copper; in fissures and shatter-planes in any part of the basalts.

The disseminated copper may be said to be universal in this area, but the best to be expected from any of it is about 0.25 per cent.

The amygdaloidal portion of the flows ranges from a few inches to several feet in thickness. In places this material will assay several per cent in copper, and in others the amygdules are entirely filled with chlorite, epidote, prehnite, opal, agate, etc. Where a flow is exposed at the surface this material is rather easily eroded, and the only broad surfaces now exposed are composed of the dense lower portions of the flows; the only place where the amygdaloidal portions may be seen is usually along the cliffs, and frequently there it is covered with talus. For these reasons it was not possible to judge of the relative extent and importance of this material during the reconnaissance mentioned.

The vein-copper assumes importance in some areas where the basalts have been considerably shattered whether in cooling or otherwise, so that now they are traversed by a network of thin fissures which contain plates of native copper, or vein material containing native copper up to several per cent of the whole.

The problem which arises in prospecting this area is to find the places where the amygdaloidal copper, or the vein-copper or a combination of the two, are sufficiently developed to guarantee a large tonnage of payable ore, and it may be possible to include considerable amounts of the richer portions of the massive material, to recover the relatively small values which it contains.

Copper Sulphide Deposits.—The writer wishes to emphasize the importance of investigating the deposits of sulphides which

occur in Bathurst inlet and to draw attention to the possibilities of the occurrence of important deposits of sulphides in the limestones which are found in the Coppermine river region. In Bathurst inlet, in the southern and western portions of the region at least, there is a series of dolomites immediately underlying the copper-bearing basalts. This dolomite is exposed in several places in cliffs about the border of the area, and in three different occurrences, a few miles apart, bornite was seen to have partly replaced the dolomite for several feet below the contact. Some of the thin layers were completely replaced, and others had masses

Thin bedded dolomite, partly replaced by bornite and overlain by copper-bearing amygdaloid. Bathurst inlet, August, 1915.

of bornite scattered through them. The total amount of this material would probably have to be determined by drilling. An analysis of material from one layer six inches in thickness gave 49.87 per cent copper.

Besides the bornite which replaces the dolomites, there is a considerable amount of chalcopyrite disseminated through some of the large sills or dykes of diabase which traverse the region.

A grab-sample, taken from one of these impregnations gave 1.18 per cent of copper.

ACCESSIBILITY

The deposits in Bathurst inlet are situated on tide-water and could be reached by ship around Alaska and eastward along the north coast through Coronation gulf. In an average season the ship should reach there some time in August, but would probably have to winter in that region.

Under present conditions the deposits in the Coppermine river region can be reached best by way of the Mackenzie river and across Great Bear lake. They could be reached by this route by the middle of August, and the party would have to winter in the country.

CLIMATE

The climate of the region under consideration is not extreme; in winter the temperature seldom drops below − 40 degrees F., and seldom rises above 60 degrees F. in the summer. The snowfall is about two feet and the snow is nearly all gone by the first part of June. There is very little on the ground before the middle of October. The rivers are open in the first part of June and do not freeze again until the end of September. Surface work could be carried on from the middle of April until the middle of October without discomfort, and there should be little difficulty in carrying on underground work during the whole year.

POWER AND FUEL AVAILABLE

Waterpower in abundance for mining operations, and probably enough for local transportation, is available from the Coppermine, Tree, and Hood rivers; the Coppermine river at Bloody falls, is sometimes open all winter.

Coal which varies from lignite to bituminous has been reported from the north shore of Bear lake, from the Horton river, from the northeast coast of and in central Bank's island, and on the southern parts of the Parry islands.

Oil is known to occur in seepages in the Mackenzie valley as far north as Fort Norman, and the possibilities of production are being investigated by drilling.

Falls on Tree river, six miles from Coronation gulf.
June, 1915

There is plenty of spruce at the east end of Great Bear lake and in places between that lake and the Coppermine river. The tree-line is within 20 miles of the coast on the river.

Transportation

The main difficulty in prospecting or opening up the deposits of copper in Arctic Canada is apparently one of transportation. The problem is simply this: there are two large areas of copper-bearing rocks which are to be tested to determine if there is a sufficient tonnage of commercial ore to warrant the expenditure of the large capital required to place the district on a producing basis.

To carry out this testing, using present means of transportation, the parties would have to spend at least one winter

in the country whether they went in by boat or overland by way of the Mackenzie river route. The party could be placed on the ground in August at the earliest and have about three months for work the same year before having to settle down for the winter; the next spring they could start in May and work until the middle of August before returning. Thus it is seen that in 18 months' time they could accomplish six and a half months' work. They could double this working time by remaining another 12 months; that is, in 30 months' time they would accomplish about 13 months' work of actual testing. These figures are assuming the best organization, management, and knowledge of the country. By using aeroplanes a party could spend between 5 and 6 months each year in actual testing, and it would not be necessary to keep the men in the north during the winter. Since the cost of labour is the largest item, it will be readily seen that the saving in wages, not to speak of provisions and outfit, would be an important factor in figuring out the relative economy of the two methods of transportation. For the investigation of the deposits of native copper in Arctic Canada by aeroplanes or hydroplanes, the most suitable base, which is easily accessible to railway lines, is on Great Slave lake.

Fort Reliance at the east end of the lake would be the best base for operations in the Bathurst inlet region, and Fort Rae, on the northern arm of the lake, would be best suited as a base for an investigation of the Coppermine river region. From either place the route would be along rivers and chains of lakes for the major portion of the distance, and, by the use of hydroplanes, intermediate bases could be established as desired.

The total distance from Fort Reliance to Bathurst inlet is only 260 miles, and by using Aylmer lake and Beechey lake as intermediate bases this would be split up into three parts, each of 100 miles in length, and practically the whole distance would be over water.

The total distance from Fort Rae to Dismal lake, which is in the centre of the Coppermine river district, is 315 miles, and

this can be split up as desired by forming intermediate bases along the chain of large lakes which occur on this route.

It will thus be seen that by using an air-service, the trip can be accomplished in a few hours. Under present means of travel it would require two months, with the expenditure of a great amount of energy and many chances of delay or even of failure.

THE CORONATION GULF COUNTRY*

By K. G. Chipman

(Annual Meeting, Montreal, March 1919)

For over 200 years there has been more or less interest in the copper of the Coronation Gulf country. The expedition of Samuel Hearne in 1770-72 was undertaken to investigate the mountains west of the Coppermine river as the source of supply of the copper in common use by the Indians. In the 19th century Franklin, Dease, Simpson, and Rae mention the copper of this country. In 1902, David T. Hanbury brought additional information. In 1911, Dr. James Douglas sent in a small party to investigate the vicinity of the Coppermine river. The results of this investigation were presented to the Canadian Mining Institute at the Ottawa meeting in 1913. Realizing the advisability of further work, more particularly in the Coronation Gulf country, the Geological Survey, in 1913, sent in members of its staff as a part of the southern party of the Canadian Arctic Expedition. The geological results of this investigation by J. J. O'Neill have been published in the summary reports of the survey for 1915 and 1916. Still more recently the Royal Northwest Mounted Police patrol under Inspector French in the country from Baker lake to Coronation gulf, brings back further reports of quantities of copper.

These reports, particularly those of the Douglas expedition and those by Mr. O'Neill, have aroused considerable interest in the country. There have been numerous requests for information not only with regard to the copper, but also to the many features of the country which of necessity would have a direct influence on any possible commercial undertakings. It is proposed in this paper to give as much as possible of this general information, as gathered during the writer's two years in the country as geographer of the southern party of the Canadian Arctic Expedition.

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* By permission of the Director, Geological Survey of Canada.

OCCURRENCES OF COPPER

Samuel Hearne in 1771 visited the Coppermine river not far from its mouth, in search of copper. In 1821, Sir John Franklin went down the Coppermine and visited the Copper Mountain area, which is just west of the big bend of the river. This was also the area of special investigation by the Douglas

expedition in 1912. The Eskimos of the present day, in their search for copper, annually visit an area which is rather more to the north and west. They start west from a point ten or fifteen miles from the mouth of the Coppermine. This latter area has never been visited by white men.[1]

Copper has been mentioned as occurring at several places in Coronation gulf, most definitely by Hanbury as occurring on Kanyuak (Eskimo name for copper) island. This vicinity was an area of special investigation by Mr. O'Neill.[2]

For the Eskimos, one of the main sources of supply is on Victoria island, in a range of mountains or hills which is in sight to the northeast from the head of Prince Albert sound. Eskimo reports indicate that this supply is a plentiful one, but this area as well has never been visited by white men.[3]

During last year the police patrol report the finding of copper about 70 miles east of Gordon bay on Bathurst inlet. On their sketch map, made during the patrol, there appears the name Kanuyak, which, as already stated, is the native name for copper.[4]

ACCESSIBILITY

It is difficult and expensive to reach the country, but it is not inaccessible. The journey entails hard work, many delays, and considerable expense, but it can be accomplished.

For a small party intending to remain in the country for a short period only, the aeroplane offers the best solution. From a base at the east end of Great Slave lake it is less than 400 miles to any part of the area. For four months or longer in the summer, flying conditions are excellent and it is entirely feasible to establish a line of communication into the country, with bases for gasoline and supplies more than sufficient to allow a small party to do very efficient work and to return to civilization in the same season.

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[1] This general area is indicated on the map as 1.
[2] Indicated on the map as 2.
[3] Indicated on the map as 3.
[4] Indicated on the map as 4.

With a base on Great Slave lake the whole of the work could be done in the one season. The ice on the lake breaks up about the 1st. of July (some years earlier) and a base at the east end could be established at the end of June or early in July, in which case July, August, and September would be available for work in the country.

The same advantage of doing the work in the one season would apply to following the Mackenzie river and Great Bear lake with a hydroplane. This would enable a base to be established nearer to the field of operations, but the distance for flying would be much greater.

Canadian Arctic Expedition's schooner, *Mary Sachs*, in the ice, August, 1913.

The round trip could also be made by aeroplane in one season from Chesterfield inlet, on the Hudson bay side. The distances, however, are greater, and navigation in Hudson bay would not permit of an early entry into the country.

For a larger party whose intention it was to remain in the country for a longer time, it would seem necessary to take in a ship from the Pacific. No person familiar with ice conditions

in the Arctic will make too positive a statement as to what can be done in a season; but it is a fairly reasonable statement to make, that in an average season a ship can be taken from the Pacific into Coronation gulf. It is also a reasonable statement, that it is doubtful if the return trip to the Pacific could be made in the same season. In 1913, it was impossible to get in, or out, past the Alaskan coast—six ships tried to get in and failed, and two failed to get out. In 1914, one ship with inexperienced ice navigators failed to get in, while another ship with experienced men got in and out. In 1914, we went from Herschell island to our headquarters on August 24th without any difficulty. In

Ice conditions, north coast of Alaska, August, 1913.

1915, we could not get out of our harbour to go west until August 12th, but during the latter part of August and all through September navigation was open. In 1916, our boat got out and to the west in July. In 1916, the Hudson's Bay Company's boat failed to get into Dolphin and Union strait, but it would seem that they turned back too soon—had they waited they would have been successful.

So far as is known, ships can usually reach Herschel island about August 10th. Dolphin and Union strait is not

free of ice by that time, but it is almost certain to be by the end of August or early in September. Coronation gulf is free of ice before this, but after a ship has arrived in Coronation gulf and has been unloaded, it is doubtful if she could return to the Pacific in the same season.

Except for work in the vicinity of the Coppermine river, the Mackenzie river route need not be considered. The Douglas brothers spent from May 25th to July 24th transporting their small outfit from Athabaska to the east end of Great Bear lake. They were able to do a small amount of work that fall, none during the winter, and a further limited amount during the spring. The police patrol spent from June 10th to August 8th on the same difficult journey. The route entails limited transportation, hard work, many delays and limited accessibility, which are out of proportion to the results attained.

CHARACTER OF THE COUNTRY

The outstanding feature of the country is that it lies entirely in the Barren Lands. In river valleys and sometimes near the lakes, patches of dwarf willow and black birch are found, but generally speaking there are no trees or shrubs. In the summer, grass grows to some extent and flowers are common and very beautiful.

The diabase of Coronation gulf dips to the north, giving a gentle slope on the north side of the hills and usually a steep slope, or cliffs up to 200 feet high, on the south. Valleys between these hills usually have lakes and swampy ground. Vegetation is abundant.

The granite country is different from the diabase areas. The slopes are more varied, and the country is much more rugged.

Generally speaking the coast line is well defined and the country gradually increases in elevation as one goes inland. Much of the inland country is rolling, with gentle slopes. Travel is easy and good grades are readily found.

TRANSPORTATION

In Coronation gulf the break up of the ice occurs in the latter part of July, and the ice disappears in a very few days. The harbours and sheltered water freeze up early in October. The period of open water may be relied on only through August and September. During these two months one can go anywhere with any type of boat available.

For perhaps a month before the 'break up' and for a month after the 'freeze up,' the ice is not safe. During the remainder of the winter season travelling is done by dog team. Dogs and dog teams form a never ending topic of conversation and argument in the north. Dogs, sleds, harness, methods of hitching, feed, etc., vary in different parts of the Arctic and are all quite different from those which give the best results in a timbered country. Dogs from the interior want fish for food and will not eat seal meat, while those from the coast want seal meat only. The toboggan as used in the interior is of little use on the coast. Sleds vary in type from the toboggan of the interior to the light, easily broken and easily repaired Greenland sled, the heavy, unwieldy but easy sliding native sled of Coronation gulf, the Point Barrow or Alaskan native type which has little to commend it, and the Nome sled which is a native type, adapted and improved by the white man. Dogs vary from the long legged, spare framed, shorter haired dog of the interior (adapted and trained for speed, lighter hauls, and soft snow) to the long haired, short legged, broad chested, heavy framed dog of the coast, adapted to heavier and slower hauling where the snow is not soft and living conditions are tougher.

Any white man going into the country will probably find that a sled of the Nome type is the most suitable. This sled will carry more and 'stand up' better than any other type; also, it can be handled much more easily, is well suited to the country, but requires more care and is not so adaptable to different conditions. Generally speaking, a team will haul 100 pounds per dog with a Nome sled, although it was usual to start out for long trips with as much as 150 pounds per dog. We

found that a seven dog team, with the Nome sled and Nome harness, gave the best and most economical results.

Dog-team with Nome sled and harness.

For inland travel in the summer, packing by dogs and men is the only method. Good dogs will pack about fifty pounds.

INHABITANTS

In the area under consideration the Eskimo population numbers about 350. The distribution is as follows: Dolphin and Union strait, 100; western Coronation gulf, 100, and eastern Coronation gulf, 150. In addition to these there are about 215 along Prince Albert sound and Minto inlet on Victoria island, and about 100 along Dease strait and in the southern part of Victoria island.

The language varies slightly from that of the Eskimos on the Mackenzie river, or on Hudson bay, but an interpreter from either place would be satisfactory.

There is no tribal organization among these people. They are usually divided into small groups of perhaps four or five families, and these groups are fairly constant although the

families of which they are made up will change from season to season. These groups live in places where there is good hunting or fishing and the number in the group depends on how many people the country will support. The groups have no organization, nor have they any chief. There are among them men of greater influence than others but this influence is due entirely to physical prowess, skill as a hunter, force of character, or reputation for magical power. They have no law other than custom. Usually any violation of established custom is supposed to be punished through spiritual power by sickness or death, or by poor results in hunting or fishing.

In the absence of established authority the greatest check on any wrong-doing, such as theft, is the extreme intimacy of the social relations. Every person knows what every other person says, does, or owns. Theft frequently occurs but usually some one will tell who the guilty person is. For punishment in a case of that sort physical force is frequently resorted to and this may lead to murder. While we were in the country one man remarked to another who was making a knife, "That is a poor knife you are making." The man finished the knife, and saying, "I'll show you the sort of knife I'm making," killed the offender with it. Usually a murderer travels to some other part of the country for a few years, and his crime becomes forgotten or outlawed.

The morals of these people are not high, but they must be considered as unmoral rather than immoral. Interchange of wives is common, in fact when a stranger comes to a camp it is a hospitable custom to offer him a wife for the time he is there. Polygamy is frequent and polyandry not unknown. Infanticide is common—if twins are born one is always killed, the girl if there is one. On the other hand the aged and infirm are well cared for. It must be remembered that these people are very primitive. Before we arrived many of them had never seen a white man and none had seen more than four or five. Their food was *entirely* meat and fish, their weapons were spears, or bows and arrows, and their clothing was entirely of fur. They started a fire with two pieces of pyrite, and seal oil furnished

both light and heat. They had no means of written communication, nor could any of them count above five; in fact, they have no word for any numeral above this number

They have no permanent dwelling places. In summer their life is migratory and they live in tents of caribou skin. In winter they live in snow huts exclusively. During the period in the winter when the sun is not visible, they have their holiday season with dancing going on almost continuously; they also have many exhibitions of magical power, trials of physical strength, etc. These are happy days for them, as they are camped together in large gatherings and, as seals are usually abundant, the daily work of a few men will keep the camp supplied with food and fuel.

The food supply is limited to meat and fish—seals and caribou form the bulk of the meat, with bears, musk oxen, hares, and squirrels supplementing this to a small extent. Food is shared in common, but weapons, clothing and household utensils are private property. Seals are obtained only in the winter, by spearing through the ice. They furnish the only food

Summer migration of Coronation gulf Eskimos, Coppermine river, June, 1916.

during a large part of the winter as well as skins for clothing, and the blubber which is necessary both as food and fuel. In the spring and fall when the caribou are migrating they are easily secured and stores of food are usually laid up. Later in the spring fish are obtained in quantities by spearing as they travel up the shallow streams to the lakes. Quantities are usually dried to form a reserve of food. Fish nets would be of great benefit to these people.

As stated above, their summer life is migratory. The old people and children are left in camp with stores of food, or at places where food is easily procured, and the more active people leave for the season. These trips are usually inland to secure wood for sleds, tent poles, and various household uses; to trade, to collect copper for making spears and other implements, and to obtain the August or September caribou skins which are needed for clothing. In travelling, they pack their equipment both on the backs of the dogs and on their own. Frequently they stay in the timbered country until the snow comes and then return to the coast with the new sleds they have made. The writer has had a taste of this summer life and it is the most care free existence he has known. The daylight is continuous, the weather and country are pleasant, lakes, abounding in fish, are everywhere and the caribou are plentiful enough to make the food problem one of little concern.

LABOUR SUPPLY

The employment of these people for work can hardly be considered seriously. They have no conception of service and their existence has always been one of independence, aside from the necessity of procuring food and clothing. Moreover, their life has always been a wandering one and it is difficult to conceive of them as settling down and working according to a white man's way of doing things. Further, the number of them is very small. Their employment to some extent in transporting supplies or in hunting is, however, quite feasible. If a man wanted a new rifle he would 'freight' goods or bring in meat until the rifle was paid for. Then he would probably wish to go and use his

rifle until the ammunition was exhausted. Or, during the seasons of the year when food was difficult to secure, he might work for a while until he wished to go inland, or on a hunting or visiting trip. To his primitive mind there would be no reason why he should not go. He would not understand any argument of his having agreed to work, and any attempt to convince him would probably end in trouble, as happened when Radford and Street were killed in Bathurst inlet in 1912, and two Catholic priests were killed on the Coppermine in the fall of 1913. .

With regard to taking Indians into the country, it should be remembered that they have a great fear of the Barren Lands. They are a people whose lives have been spent in the timbered country and they think it impossible to live in a country where there are no trees. The Eskimo, with his knowledge and training, is completely at home in the Barren Lands while the Indian is completely helpless. They go to the edge of the Barren Lands to hunt caribou, but they will not go far from the timber.

RESOURCES

Other than copper, the chief asset of the country is fur, and this is not a very large one. On all parts of the Arctic coast, white fox is the chief source of supply. During the winter, these animals are found on the ice near open water where they obtain their food from the remains of seals which have been killed and dragged up on the ice by polar bears. As Coronation gulf is completely frozen over during the winter there is no open water in which seals can be caught. Consequently there are no bears in this area and the white fox has to make a living on the land. On this account they are not plentiful around Coronation gulf and the supply would soon be exhausted. The other sources of fur can only be considered as of little importance from a commercial point of view.

Caribou and fish are plentiful and, during times of food shortage, might become of use to the outside world. This question is essentially one of transportation. The former can easily supply all the meat that is needed for any body of men in the

country. They migrate to the north in the spring and return to the south after the 'freeze up,' when they can be procured in any desired quantity. The meat can easily be cured and stored until needed.

TRADING POSTS

In 1916, the Hudson's Bay Company sent in a power schooner to establish a trading post among the Eskimos of Coronation gulf. The post was established at Bernard harbour on Dolphin and Union strait where we had our headquarters for two years. In 1917, the Northern Trading Company also despatched a schooner for the same purpose. This schooner did not get in during that year, but expected to do so in 1918. Their post will probably be established at the mouth of the Coppermine river or in that vicinity. Since we came out in 1916, two or three small trading schooners have also gone into the area. None of these can be relied upon to any extent for supplies or outfit—the subject is referred to simply to show that people are going in there. These parties are very small and are there primarily for *trade*—such outfit as they have is very limited and is only adapted to trade with the natives. Any other parties going in would not want the sort of equipment that traders carry—and the latter would not willingly dispose of it except in trade with the natives.

Anglican missionaries have been in the country since 1916 and it is expected that Catholic missionaries will also be there soon. The latter, at Fort Resolution, now have an Eskimo family from Coronation gulf for the purpose of learning the language and customs of the people, and whom they are instructing at the same time.

CLIMATE

The country is subject to fewer extremes of temperature than is northern Ontario or the prairie provinces. During three years on the Arctic coast we had no temperature lower than — 50° F. in the winter, nor can the writer recall any above 76° F. in the summer. The mean temperature for November, 1913,

was − 0.3° F., for December − 17.2° F., for January − 18.2° F., and for February − 24.2° F. The record of the mean temperatures during June, July, and August is not available, but it would be approximately 45° F.; during September it would be somewhat lower.

In Coronation gulf there is continuous daylight for more than two and a half months in the summer—May 10th to August 1st. For about one and three-quarter months of this time the sun is continuously above the horizon. On the other hand, during December and January the sun does not appear above the horizon for over a month. This period is not entirely dark for there are from five to six hours a day of very fair light.

Precipitation is very light. The snowfall in the winter is less than two feet, and in the summer there is seldom any rain. The ground is usually free from snow for three or four months during the year.

The cold is by no means extreme on Coronation gulf, but a penetrating wind blows almost continuously. The writer has seen dogs from the interior, who were accustomed to a dry, windless temperature of 60° or 70° below zero, miserably cold in zero weather on the coast. As previously stated, Coronation gulf is completely frozen over in the winter, and the cold is accompanied by less humidity than in other parts of the Arctic where there is open water during this season. Blizzards are common, but are neither as frequent nor as severe as in a more mountainous country, or in one with more open water. Air conditions are also more stable.

CLOTHING

There is no doubt that fur clothing is best suited to the country. It is lighter, more comfortable, and warmer than any white man's clothing that could be taken in. That worn by the Eskimos of Coronation gulf, however, is not very satisfactory for the use of white men. Anyone with experience along this line could have suitable clothing made in the district, but the maximum comfort can be secured from the clothing made by

the Alaskan Eskimos. They select and dress the skins more carefully; also, the clothing is better made, and the design and fit are, in every way, more satisfactory for the use of the white man. The fur used for clothing is almost invariably that of the caribou killed in the early fall before the fur has grown too long.

A sleeping bag made from heavy caribou skins is lighter, warmer, and more comfortable than either blankets or eiderdown. The writer's sleeping bag, weighing nine pounds, with a light canvas cover (weighing three pounds) to keep out the snow, was comfortable at any temperature.

For use in the summer, the clothing of the white man is better than that of the Eskimos; but for the greater part of the year, Eskimo clothing is to be preferred.

TIMBER

The area, as a whole, is well beyond the northern limit of timber. On the Coppermine there are a few spruce trees within twenty miles of the mouth, and thirty miles farther up the river there are areas of timber which cover several hundred acres, but for any quantity of good timber, Great Bear lake and its vicinity must be considered as the nearest source of supply.

The Mackenzie river, 600 miles to the west, carries down large quantities of driftwood, small amounts of which find their way into Coronation gulf. The quantity, however, is small and is of value only for small parties travelling in the summer when the beaches are not covered by snow.

MAPS

Existing maps have been compiled from the route traverses and sketches made by Franklin, Dease, Simpson, Rae, Richardson, Back, Hood, and other early explorers. Some of the route traverses are good and others are not. The compilation of these has probably introduced some errors which are not present in the original sketches, and the mapping of the country between the routes is very vague. In using these traverses as maps the

conditions under which they were made must be taken into consideration. Most of them were made when the party was striving to attain a definite objective, or at least, as near that objective as possible. The result was that speed of travel was the important factor and too much attention could not be paid to the details. In following a coast line, for instance, it was usual to travel from point to point, and consequently the bays are lacking in detail. On the other hand, details which do not exist were sometimes put in. For example, from a distance a bluff or other high land appears to be a point and low land on either side seems to be a bay, whereas the reverse may be the case.

The geographical location of points on present maps is accurate in places and incorrect in others. This is due to the fact that the observations usually extended over considerable time and area with no opportunity to check the accuracy of the instruments. Althongh these may have been in perfect adjustment when first taken away from the base, they may later have become damaged to such an extent as to impair the accuracy of the remainder of the map. By one who considers the difficulties under which these maps were made, they must be regarded as a high tribute to the men who made them. At the same time they must not be relied on too completely for details.

For all work on the coast, the British Admiralty chart, 2118, is the best map. For the interior country there is little information available, but what there is has been compiled on the 35-mile-to-an-inch map of Canada. Our own work covers about 1,200 miles of traversing, of which over 800 is on the main coast line, and the balance on rivers and islands. This work is available and will be found accurate.

In conclusion, the writer wishes to state that further investigations in the Coronation gulf country may be difficult and expensive; but it is entirely feasible to undertake them. If these investigations indicate copper of economic importance, further difficulties can also be overcome.

NOTES ON THE SALT INDUSTRY OF CANADA, WITH SPECIAL REFERENCE TO THE RECENT DISCOVERY OF ROCK SALT IN NOVA SCOTIA.*

By L. Heber Cole

(Annual Meeting, Montreal, March, 1919)

In view of the recent discovery of rock salt in Nova Scotia, a few notes on the possibilities of utilizing this mineral in Canada may be of interest.

Beds of salt, and salt springs, have been known in Canada for many years and the former have been worked in Ontario for over half a century. Numerous salt springs are found in Nova Scotia and New Brunswick as well as in northern Manitoba and northern Alberta. There are also a few isolated localities in British Columbia where springs containing sodium chloride are known to occur. Until recently only the deposits in Ontario have been worked to any great extent. The Manitoba springs are, in nearly all cases, situated in districts at present inaccessible for economic development. They have never been found as a saturated solution, although they average about 25° salinity. The source of the salt found in these Manitoba brines has not yet been discovered and there is good opportunity for prospecting work to determine whether these brines come from beds of rock salt lying to the west.

The Ontario deposits consist of beds of rock salt lying at a depth varying from 1,000 to 2,000 feet below the surface, and the salt is obtained by dissolving the rock salt 'in situ' with water and evaporating the saturated brines which are thus obtained. None of the rock salt is being mined in the solid, at the present time, in Ontario.

The brines of the Maritime provinces are also of a low degree of salinity and until the discovery of rock salt was made at Malagash, Cumberland county, no deposits of this mineral

* By permission of the Director, Mines Branch, Ottawa.

had been worked to any extent in those provinces. The principal salt springs in the Maritime provinces occur at Whycocomagh, C.B., in the vicinity of the village of Antigonish; at Spring Hill, Cumberland county; Salt Springs, Pictou county; and at Walton and Cheverie, Hants county, all in Nova Scotia; also at Sussex, Salt Spring Creek, and Tobique River, Kings county, in New Brunswick. A deposit of rock salt of considerable thickness is now being developed in the neighborhood of Malagash, Cumberland county, Nova Scotia. This is the first known discovery of rock salt in the Maritime provinces and the first in Canada to be discovered at a depth sufficiently shallow to enable it to be produced economically by actual mining.

DISCOVERY AND HISTORY OF THE DEPOSIT

In 1912, Peter Murray drilled a well for water on his farm on the Malagash road, about 7 miles northeast of Malagash station. He encountered salt water of which he sent a sample to Dr. Shutt of the Dominion Experimental Farm, at Ottawa. Dr. Shutt reported on this sample as follows:

"Our analysis of this water shows it to contain 28.83% total solids, of which 28.32% is common salt. It is, in fact, a very strong brine. There are present very small quantities of sulphate of lime and possibly of allied compounds, but essentially this is a saturated, or practically saturated, solution of common salt."

No action was taken with regard to this discovery until the early part of 1917 when another sample was forwarded to Dr. Shutt, who reported 26.65% common salt present. At this time Dr. Shutt referred the people interested in the matter to Dr. Haanel, Director of the Mines Branch, Department of Mines. The Mines Branch immediately obtained another sample and had it analyzed. It was found to be a saturated brine, its analysis being given in the following table, together with four analyses of brine from the Western Ontario district, for comparison.

TABLE I.

1,000 parts by weight contain:

	Malagash, N.S. Brine	Western Ontario Brine			
Sodium (Na)	99.50	96.270	101.728	96.368	100.997
Potassium (K)	0.55	n.d.	n.d.	n.d.	n.d.
Iron (Fe)	0.07	n.d.	n.d.	n.d.	n.d.
Calcium (Ca)	1.37	1.552	1.630	2.496	1.531
Magnesium (Mg)	0.22	.224	.257	.127	.118
Sulphuric Acid (SO_4)	3.11	2.631	2.634	1.698	2.803
Chlorine (Cl)	154.70	150.122	158.742	152.294	156.884
	259.52	250.819	265.001	252.983	262.333

HYPOTHETICAL COMBINATION:—PARTS PER THOUSAND

Sodium Chloride (NaCl)	252.90	244.860	258.770	245.111	256.891
Potassium Chloride (KCl)	1.04	n.d.	n.d.	n.d.	n.d.
Magnesium Chloride ($MgCl_2$)	0.86	.966	1.017	.503	.467
Calcium Chloride ($CaCl_2$)	0.22	1.265	1.484	4.964	1.007
Calcium Sulphate ($CaSO_4$)	4.42	3.728	3.730	2.405	3.971
Ferric Oxide (Fe_2O_3)	0.10	n.d.	n.d.	n.d.	n.d.
	259.54	250.819	265.901	252.983	262.336
Sp. Gravity at 15.5°C	1.200	1.197	1.2045	1.178	1.198

As a result of this analysis the writer suggested that further exploration was desirable in order to ascertain if the parent salt bed could be located. When the area was visited in June, 1917, brine had been encountered in several other holes. A personal examination of the local conditions convinced the writer that there was a possibility of the existence of rock salt and he strongly advised the owners to continue their prospecting. Subsequent development has demonstrated that these deductions were sound.

In the summer of 1917, A. R. Chambers and George McKay, of New Glasgow, became interested in the operations and drilled a series of holes, after which they sank a prospect shaft in June, 1918. In this shaft, rock salt was encountered at a depth of 85 feet from the surface and when visited on October 10th, 1918, it had reached a depth of 17½ feet in the salt formation. Since

then the writer has been informed that the shaft has penetrated about 25 or 30 feet in the formation and that they are now drifting on the deposit.

The overlying strata penetrated by the shaft appear to be in a nearly horizontal position and consist of clays, soft shales, gypsiferous muds, etc. The underlying saline beds appear to dip to the west of south at an angle of about 25° and have a strike of S. 70° E.

The saline beds, as encountered in the shaft, show, in the upper 12 feet, considerable impurities in the form of mud, but whiter rock salt is now being excavated at the bottom of the shaft. The indications from a drill hole located on the site of the shaft are that the salt beds have a thickness, at this point, of nearly 50 feet.

The saline beds are found associated with beds of gypsum mapped by Fletcher as of Lower Carboniferous age. These gypsum beds are seen exposed on the shore to the north of the shaft. To the south of the shaft there is a small unmapped outcrop of what appears to be New Glasgow conglomerate. The salt beds are on the south slope of an anticline, and, so far, little is known as to their lateral extent. To the west, about a mile from the shaft, there is a pronounced fault shown in the shore section, and this may cut off the western extension of the beds. To the east, at about the same distance, the occurrence of a marsh, caused by the sea eroding the northerly lying and protecting sandstone barrier, may determine the eastern extension of the deposit. The evidence at hand, however, indicates the presence of a salt formation of considerable extent. Based on data obtained from the shaft, from surface indications, and from the drill holes, it is possible that the saline formation, measured at right angles to the dip, may have a thickness of 175 feet.

A general sample of the whiter rock salt was taken for analysis, with the following results: (Analyst, Mr. T. W. Hardy.)

TABLE II.

DRIED AT 110°C

Sodium (Na)	38.45
Potassium (K)	0.20
Iron and aluminum (Fe and Al)	none
Calcium (Ca)	0.25
Magnesium (Mg)	trace
Sulphuric acid (SO_4)	0.61
Chlorine (Cl)	59.35
Insol. in water	1.05
Total	99.91

CONVENTIONAL COMBINATION

Sodium chloride (NaCl)	97.60
Potassium chloride (KCl)	0.40
Magnesium chloride ($MgCl_2$)	trace
Calcium chloride ($CaCl_2$)	none
Calcium sulphate ($CaSO_4$)	0.86
Ferric oxide (Fe_2O_3)	none
Insol. in water	1.05
Total	99.91

Although the quantities of potash salts present in the two samples examined from this locality are small, it does not of necessity mean that they are absent in commercial quantities in this area. The drilling and prospecting so far carried out have only in the most superficial way indicated the presence of a large bed on one horizon, and the finding of potash salts, interbedded with the sodium chloride on horizons other than the one penetrated by the prospect shaft and drill holes, is quite within the bounds of possibility.

The importance of this discovery to the Maritime provinces can readily be seen. The only salt producing district in Canada at present is the Western Ontario district. The Maritime provinces consume about 50,000 tons of salt in the fishing industry each year. Owing to the prohibitive freight rates from Western Ontario, this salt has to be procured either from England, Spain or the West Indies. On the Atlantic seaboard

of the United States, as well as in Newfoundland, a considerable tonnage of salt is imported for the curing of fish, etc. It is evident, therefore, that the establishment in Nova Scotia of a modern salt manufacturing industry producing suitable grades of salt, would prove to be a profitable commercial enterprise.

In order to emphasize the possibilities of this discovery the writer wishes to briefly review the methods of preparing salt for the market. The accompanying flow sheet (Fig. 1), shows graphically the method of obtaining commercial salt from either natural brines or rock salt.

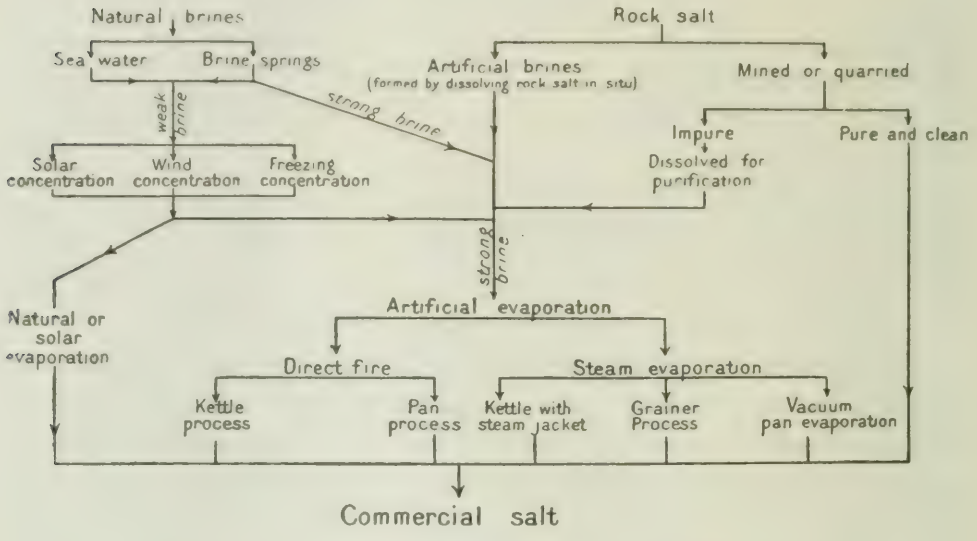


Fig. 1—Flow sheet showing method of salt recovery

Fig. 2 shows the flow sheet of a salt plant obtaining commercial salt by the open pan method.

Aside from preparing salt for the market, there is also the possibility of establishing an industry on the Atlantic seaboard for the production of sodium compounds, using salt as one of the raw materials. These compounds may briefly be referred to as follows.

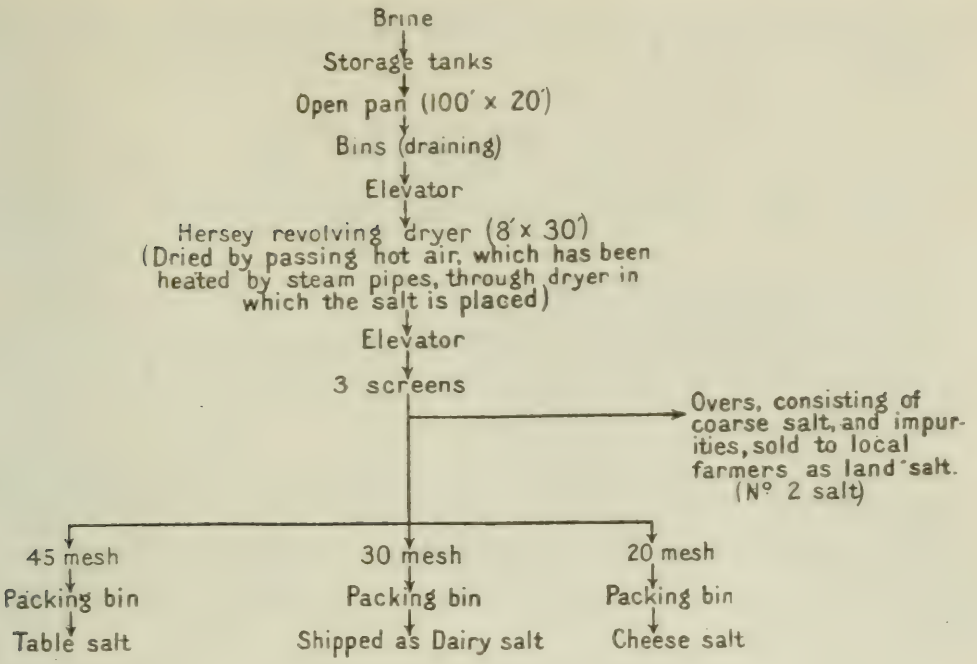

Brine
Storage tanks
Open pan (100' x 20')
Bins (draining)
Elevator
Hersey revolving dryer (8' x 30')
(Dried by passing hot air, which has been heated by steam pipes, through dryer in which the salt is placed)
Elevator
3 screens
Overs, consisting of coarse salt, and impurities, sold to local farmers as land salt. (N° 2 salt)
45 mesh
Packing bin
Table salt
30 mesh
Packing bin
Shipped as Dairy salt
20 mesh
Packing bin
Cheese salt

Fig. 2—Flow sheet for open pan method

CAUSTIC SODA (SODIUM HYDRATE)

Until the last 50 years the manufacture of caustic soda was not extensive. The most common process in preparing this material was the one in which advantage was taken of the reaction of sodium carbonate and slaked lime. This process at first entailed the production of soda ash. Of late years, however, caustic soda has been prepared by the direct decomposition of sodium chloride in an electrolytic cell, producing chlorine gas and metallic sodium, which latter at once unites with water present in the cell to form caustic soda. The weak solution of caustic soda thus produced is concentrated in vacuum pan evaporators. From these evaporators the solution passes to storage tanks after passing through separators—to eliminate the sodium chloride. The final concentration is then carried out in finishing pots of about 18 tons capacity and the pure caustic soda is run from the final pot into iron drums (700 lbs. capacity) and allowed to solidify. The product is then ready

for the market. One firm is already making caustic soda in Canada by this process.

SODIUM CARBONATE (SODA ASH)

Although sodium carbonate is often found in extensive natural deposits, it is generally very impure. Owing to the cost of dissolving, evaporating and purifying, it rarely pays to operate a deposit of this nature except at actual points of consumption, as commercial sodium carbonate can be prepared artificially from sodium chloride at less cost.

In the artificial preparation of sodium carbonate there are three processes of importance which use sodium chloride as a raw material. These three processes are (1) the Solvay, or ammonia-soda process, (2) the electrolytic process, and (3) the Le Blanc process.

The Solvay Process.—This process is based on the well known reaction of ammonia bicarbonate on sodium chloride, with the separation of part of the sodium as sodium bicarbonate. The raw materials required for this process are limestone, sodium chloride (either as brine as it comes from the wells or rock salt dissolved) ammonia (either in the form of ammonium hydrate solution or ammonium sulphate) and fuel.

In brief, the essential operations in this process are, to manufacture carbon dioxide from limestone; to pass this gas into the ammoniacal brine which has previously been prepared by saturating the brine with ammonia gas; the separation of sodium bicarbonate, which forms as a precipitate, from the solution; and the calcining of this precipitate to form sodium carbonate or soda ash. The product of this method is remarkably pure and will average over 98.5% sodium carbonate, the principal impurity being sodium chloride.

Electrolytic Process.—An electrolytic process for the manufacture of sodium carbonate crystals by the electrolysis of brine has been operated commercially, on a small scale, in England. This process, known as the 'Hargreave and Bird Process,'

employs a diaphragm cell of unique arrangements. The diaphragm is impervious to the salt solution, but permits the sodium ion to pass to the cathode. As the sodium ions are set free, they are converted into soda crystals by the blowing in of steam and carbon dioxide. The sodium carbonate made by this process is very pure and will average when dehydrated 97.5 to 98% Na_2CO_3.

The Le Blanc Process.—This process for making sodium carbonate from salt consists of first making sodium sulphate—to be later described—and then fusing this with a mixture of limestone and carbon. The raw materials required are sodium sulphate (salt cake), pure limestone and a good grade of coking coal. The reactions are complex, but the process in brief is as follows: The salt cake, limestone and coal in predetermined proportions, are fused in a furnace and the fused mixture, called black ash, is allowed to cool. The black ash is then lixiviated with water and the resultant lye is purified, giving commercial sodium carbonate which will vary in composition from 75 to 98% Na_2CO_3. The finished product from this process should be white or nearly so.

Both the crystal form and the soda ash are met with in commerce. The crystal form known as soda crystals, or washing soda, has the formula $Na_2CO_3.10H_2O$. These crystals readily dehydrate and effloresce when exposed to the air.

SODIUM SULPHATE (SALT CAKE)

Like sodium carbonate, sodium sulphate occurs naturally, but owing to the artificially manufactured substances being so cheap, it seldom pays to use the natural deposits.

The most common process for producing sodium sulphate is by the action of sulphuric acid on sodium chloride. The salt for this process is preferably rock salt, or the coarsest salt produced from evaporation.

The process may be carried out in two ways; (1) sulphuric acid, as such, may be added directly to the salt, or (2) sulphur dioxide, oxygen and steam may be added to the sodium chloride.

By the first method the acid sodium sulphate is formed, and this reacts again with salt to form sodium sulphate.

In the second method, known as the 'Hargreave Process,' steam and oxygen are caused to combine with sulphur dioxide to form sulphuric acid which simultaneously attacks the salt, forming sodium sulphate and hydrochloric acid, as represented by the following equation:—

$$4NaCl+2SO_2+2H_2O+O_2=2Na_2SO_4+4HCl.$$

CHLORIDE OF LIME (BLEACHING POWDER)

When dry chlorine gas is passed over a thin layer of slaked lime, a compound is formed which will readily give up its chlorine, when acted upon by an acid.

In brief, the process generally employed in the manufacture of bleaching powder is to utilize the chlorine gas produced by the electrolytic decomposition of sodium chloride and pass it through a series of lead-lined chambers in which slaked lime is spread on the floor to a depth of about two inches. Generally a number of these chambers are operated in series. The bleaching powder is discharged through openings in the chamber floor to the shipping room beneath. It is then packed in drums of 700 lb. capacity. The percentage of 'bleach' in the chloride of lime thus produced will vary from 37 to 39 per cent. chlorine, i.e., the 'bleach' contains from 37 to 39 per cent. chlorine available for bleaching purposes.

The rapid growth of, and the commercial progress in, the Dominion during the last few years have greatly increased the demand for those chemicals in the manufacture of which sodium chloride enters either directly or indirectly as one of the principal raw materials. The increasing demand for these chemicals, as evidenced by the figures of imports shown in the following table, has naturally evoked the question whether they cannot be manufactured in Canada. This question has been partially answered by the fact that one company is already successfully producing caustic soda and bleaching powder from sodium

chloride in the form of brine, and another company has a plant nearing completion for the production of soda ash by the Solvay process. There are several other chemicals in the manufacture of which sodium chloride is used; and there is no reason why use should not be made of the salt deposits of Canada for their production. In view of the rapidly increasing market, there should be no difficulty in the disposal of the products of such plants.

TABLE III.

IMPORTS OF CAUSTIC SODA AND CHLORIDE OF LIME

	CAUSTIC SODA		CHLORIDE OF LIME	
	Pounds	Value	Pounds	Value
1912	14,544,545	$278,579	12,183,765	$113,346
1913	15,983,298	291,008	12,761,153	115,614
1914	18,436,827	314,278	15,147,645	138,619
1915	7,737,149	184,468	12,015,999	112,142
1916	12,502,758	508,860	7,892,923	158,546
1917	13,694,560	643,178	7,719,919	100,834
1918	12,359,044	623,023	9,783,062	162,748

Note.—For purposes of comparison, the pre-war years—1912-13-14—should be examined.

It will thus be seen that the requirements of the Canadian market alone for salt would guarantee the successful operation of the deposit at Malagash, and its favourable location on the Atlantic seaboard would probably lead to the development of an export trade with the United States and also South America and South Africa.

TUNNELLING AT THE FRONT

By Major R. W. Coulthard

(Annual Meeting, Montreal, March, 1919)

Due to the peculiar exigencies of war and the obvious difficulties concomitant therewith, the methods of mining as pursued at the Front were, almost without exception, crude. There were many obstacles to be overcome—the disposal of the 'spoil,' the desultory and unreliable supply of material, the frequency of hostile shelling, other activities of the enemy, and the unspacious accommodation afforded by the narrow galleries. These imposed a few of the conditions that make war an operation which would overthrow all the specious theories and fireside calculations of that most recent fungoid excrescence, the efficiency engineer.

There were, it is true, certain phases of the technique of purely military mining, which, of necessity, were adopted and highly developed, and this drew upon the resource and skilful science which the mining engineer is known to possess in high degree. These were in respect, chiefly, of the selection of explosives, their charging and firing, methods of listening, and certain precautionary measures which the instinct of self-preservation fastened upon that notoriously casual production, the tunneller.

War is a thriftless jade. Its economics are concerned not at all with such lightsome and irrelevant things as balance sheets. Regiments, not dollars, go to the profit and loss account, and costs are reckoned in men and reputations, the latter on several occasions having, in especial, discomfited a hopeful market. Industrially and technically, therefore, one can hardly look for much enlightenment upon the economic side of mining from military tactics; and the only notable innovations, with those exceptions to which I have already alluded, were responses to the call of necessity, the product of resourceful minds and hands, but hardly applicable to practice other than that of a temporary or prospecting character. Accordingly I shall not enlarge upon the technique in any great measure but shall confine myself to an outline of mining at the front in general terms.

History.—The first attempts at organised mining in France were consequent upon the underground tactics of the Hun, brought into practice in the spring and summer of 1915. The organisations in their incipiency were called Brigade Mining Sections, comprised chiefly of miners selected from other units at the front and officered, for the most part, by mining engineers. From these evolved tunnelling companies proper, the first establishments of which must be credited to the Royal Engineers. Canada responded by making preparation to put three tunnelling companies in the field.

No. 1 Tunnelling Company was mobilised in eastern Canada by Major Rogers during the months of September, October and November, 1915. They proceeded overseas in the month of January, 1916, and to France in February of the same year.

No. 2 Tunnelling Company was recruited from British Columbia and Alberta by myself in December, 1915, and part of January, 1916. On January 15th they proceeded overseas and to France on March 10th, 1916.

No. 3 Tunnelling Company was unique from the other two in that it was a reorganising of the mining sections of the 1st and 2nd Divisions, already in France, which organisation was very efficiently carried out by Major A. W. Davis during the months of November and December, 1915.

In the beginning the call for these mining units was so urgent that great expedition in mobilising was insisted upon by headquarters, and we were given to understand that purely military training on the part of the individual make-up could be subserved to the technical and practical. This arrangement, however it might appear to be a concession, cannot be said to have been entirely without its disadvantages, especially in the infancy period, during which time the officers commanding were placed in many inconvenient and unenviable situations.

In the year 1918 a complete reorganisation of the engineering units was effected, with the result that in July last the 1st and

2nd Tunnelling Companies lost their individual identity by their absorption into engineering battalions. No. 3 Tunnelling Company, however, was fortunate in retaining its independent character.

Tunnellers heretofore had nominally been corps troops; but from this time onwards all operations were directed by an Inspector and Controller of Mines, immediately responsible to the Army Command. This latter procedure was productive of eminently favourable results, as it brought the Imperial and overseas tunnelling units into close personal touch in conference, and made for common interests and friendly rivalry in operations.

The *loci operandi* of the three companies may be particularised as follows:

No. 1 is chiefly associated with operations at the 'Bluff' and St. Eloi; No. 2 operated from the left of Hill 60 to Sanctuary Wood, which included Mount Sorrel (Armagh Wood) and Tor Top sectors; No. 3 had the honour of defending the famous Hill 60.

Throughout the section of line comprised in the above I think it can be well attested that these Canadian units conducted themselves in a manner consistent with all the best traditions. Nor can it be said that the enemy at any time had occasion to boast of getting the best of any underground argument with them. The results, which it is not within the scope of this present paper to expatiate upon, will be spoken of in history, should the latter ever record in detail the worthy exploits of the miner in the Great War.

Ground.—The mining operations of the Canadian tunnellers did not include the chalk outcrops at, and south of, Givenchy. Instead, they were confined to the soft ground between Hooge and Armentieres; this area embraces the Ypres salient of the insalubrious 1916-17 era, and the sectors immediately adjoining to the south.

In this zone the general character of the soil is a reddish sandy loam. In descending order, stratification might be:

loam, 6 feet (varying); sand (varying); running sand, from nothing to 30 feet; hard sand (varying); blue clay (London), found from 30 to 60 feet under the surface.

Operations.—Tunnelling operations may be sub-divided into (1) defensive mining; (2) offensive mining; (3) combined defensive and offensive mining.

Defensive mining was only adopted as a protective measure against underground encroachments on our lines by the enemy. Points of vantage held by us and which were accessible to the enemy by mining were thus guarded. The systems varied according to conditions. Sometimes it was necessary, owing to the enemy's activity, to take quick action. In such event a gallery would be driven directly toward the point where mining was expected or where the enemy must pass. Preparations were then made to welcome his arrival with a 'camouflet.' But where time was not a serious factor, and if the salient or vantage point was strategically important, it might be found desirable to lay down a complete system.

To accomplish this, shafts or stepped slopes were sunk to the desired level in the front or support lines. These would be located at distances apart compatible with trench conditions, cover, etc., and with the plan of the system.

From these shafts, into 'no-man's-land,' were driven parallel galleries until a point about 100 feet beyond our front line was reached. From these galleries others were then driven at right angles, approximately parallel with the front line, and connected up, making a complete communicating system. From the main front line of gallery thus formed, and at distances of 30 feet, listening posts ran out towards the enemy. These extended for 30 feet and had a right-angled jog of about 10 feet in length for the purpose of breaking the force of the back pressure from a 'camouflet,' should one be blown. At the end of this listening post sat the listener, day and night continuously. Also, from the end of the post, holes were bored forward or diagonally, or both, for a distance of, say, 20 feet. These facilitated listening with the naked ear and served also as receptacles for torpedoes,

which were cylinders charged with explosive and used in case of sudden contact with the enemy.

Offensive Mining. Offensive tactics were employed almost wholly for purposes of:

(1) Destroying the enemy's strong points or salients.

(2) Assisting in our surface attacks on the enemy's lines.

(3) Destroying or minimising hostile underground offensives.

(4) Combating hostile surface attacks.

(5) Depreciating the morale of the rank and file of the enemy and confusing the plans of his staff.

To destroy any given point or section of line it was essential to place our mines directly under the objective or as approximately so as circumstances would permit. Opposed to our achievement of this coveted position were the defensive preparations already laid, or the other activities set in motion, by the foe, who, although possessed of many unqualified weaknesses, could not have fastened upon him justly the stigma of being somniculous in the business of safeguarding himself. Resort was had, therefore, to methodical and patient reconnaissance and observations on our part in the mines themselves, on the surface, and from the air. The deductions drawn were very frequently a guidance in directing our operations.

To block and harry the enemy formed no small part of the tactics, and mines studiedly placed under 'no-man's-land', and blown with cratering effect, and synchronously with his advance, many times proved efficacious to this end. Unfortunately, these 'blows' on occasion had a marked reciprocal disadvantage to our own troops when counter-attacking. They proved to be a boomerang. Lack of opportunity to explore thoroughly the torn-up ground, the uncertainty of the location of hostile positions in and about the craters formed, and the general confusion caused by the soft, uneven nature of the surface, were features which, in a measure, effected reactionary inconvenience.

In affecting the general tone of the morale of troops or confusing certain local plans of a staff, one can readily admit the

efficacy of an occasional underground 'blow,' or the suspicion of ghoulish sounds emanating from under one's feet, from no definitely located position.

Combined Defensive and Offensive Mining.—After having completed a definite system, a change in local strategy may be planned, so that it will be deemed in the best interests of co-operation to develop the defensive into an offensive system. This operation is accomplished by advancing galleries from the front listening posts, selecting those which are found most convenient for the operation. In reverse manner, tunnels which were originally intended for offensive purposes, or which were even utilised as such, were converted into purely defensive positions if the tactics of the enemy made this necessary.

Tunnelling for Cover.—For the accommodation and safety of the men some very extensive underground systems were elaborated. Not only were permanent sleeping quarters thus provided for officers and men, but they were also utilised by the infantry for 'stand-to' purposes during a 'barrage' period. From these safe retreats the troops could then sally forth at the appointed time. A depth of 15 feet below the surface gave ample security from anything but the heaviest shells. The main galleries in such systems should preferably be 3 feet wide and 6 feet high to allow for ease in travelling. Levels driven at right angles from the main arteries and provided with enlarged chambers on each side gave the necessary accommodation. Natural ventilation was procured by frequent upcasts to the surface; these were in the form of shafts, inclines or holes bored vertically upward and sometimes cased with piping. Also the forward movement of troops was sometimes facilitated by means of underground communication ways and this could be especially adapted to taking up positions in craters from front line positions.

Location of Shafts.—This was contingent upon the following:

(1) The position of objective.

(2) Soil.

(3) Sub-soil.

(4) Composition.

(5) Topography.
(6) Local cover.
(7) Our own trench arrangement.
(8) Proximity of enemy's trenches.
(9) Hostile activities.
(10) Urgency of operation.
(11) Permanency of operation.
(12) Depth required.

All other conditions being equal, the entrance should be placed at the point nearest the objective that will require the least linear footage of tunnelling. It was rare, however, that one or more of the other considerations enumerated above did not intervene to render the adoption of the shortest route impossible. The shaft entry should be a position least exposed or apparent to the enemy's observation posts or aerial photography. The latter, especially, has been a most excellent means of detecting suspiciously new works in a trench system; and it is through studying our own works by the aid of photographs that we were enabled to deduce circumstantial evidence of the enemy's operations. Hence local assets, in the way of topographical features, or woods, etc., for concealing or 'camouflaging' our work, were essential. Also it was desirable to place the entries away from the main trench thoroughfares, but not so as to make the disposal of the 'spoil' an undue inconvenience. These properly concealed and conveniently situated locations were the more desirable in cases where the operation was likely to occupy an appreciable length of time.

Depths of Mines.—Some mines were well over 100 feet below the surface, and again, many were but a few feet. In the early stages deep mining was not undertaken. The shaft would be sunk until the ground became too wet for ordinary sinking, and the main galleries would then be driven. The advantage, however, of getting beneath the enemy's galleries was soon obvious, and this led to the application of more efficient methods for sinking through wet or running ground. In this, as in most

other mining innovations, we anticipated the 'Hun.' Ordinary case sets were sometimes sufficient for the purpose, or square sets with inside sheathing. But for running ground, other methods had to be introduced, the preferable plan being to use steel tubular shafting.

To suit transport and trench conditions this casing was obtained in sectional rings of about 2½ feet in depth and from 5 to 6½ feet in diameter, both top and bottom edges of the sections being provided with flanges turning inward and furnished with bolt holes. The method of sinking them was to bolt one ring to the other as excavation proceeded, letting the steel shaft thus formed be lowered until the running ground was reached. Here excavation ceased, and by the use of screw-jacks, sometimes as many as four or five, each of 5-ton capacity, and the addition of further sections to the steel tube, the latter was forced through the soft material until hard bottom was encountered and entered. The screw-jacks worked against the roof timbers of the shaft chamber. A cutting edge on the lowest ring was advisable, and this purpose was generally served by removing the flange.

It will be noted that no ground was taken out during this procedure. Were the soft ground removed during the lowering of the lining it would but fill up again from the outside of the tube and this would have a tendency to divert the whole casing from the perpendicular, thus involving wedging. Certain sinking operations where this precaution was not observed were rendered impossible of completion, no amount of pressure from numerous screw-jacks being effective.

When solid ground was encountered beneath the soft, it was then a simple matter to return to the use of the timber sets, if so desired. This solid ground was generally sand overlying the blue clay.

Galleries.—Although the cross-sectional dimensions of galleries were not uniform throughout in the tunnelling services, an attempt was made by the Canadian companies in the spring of

1916 to standardise them. Convenience and ample accommodation for the workers had to be taken into account; but there were the further considerations of (a) difficulty of removal of 'spoil' and (b) advisable economy in the consumption of timber, owing perhaps to inadequate supplies or transport facilities. A standard mine gallery 4 feet high by 2 feet 3 inches wide (in the clear) found approval; but conditions might arise which would necessitate a change in these dimensions, and this was left to the discretion of the commanding officers. The set consisted of two side posts, a sill, and a collar, and, if placed at appreciable distances apart, 'stretchers' or blocks were inserted. Wedges were usually driven between the roof and the collar, and cleats placed at collar and sill where they joined the posts. In wet ground the sets were placed with half-inch to one-inch spacing to allow for swelling behind the timbers. For dry ground in shallow mines, the spacing could be enlarged to 18 inches in many cases.

Very little, if any, water was encountered in the blue clay, and, when first cut, the ground would stand extremely well. When it dried, however, it was found that it had a tendency to swell or creep. In consequence, close timbering in the blue clay was imperative.

Mechanical borers were experimented with, especially in galleries of great length, but on the whole they appeared to be unsuccessful. The difficulty of preserving the gradient, and the small diameter of the bore militated against their employment. The pick and shovel method was the usual one, and by this means some remarkable progress was made. From 20 to 30 linear feet per day was a quite common advance and 50 or more feet has been recorded. All dirt was filled into sandbags and conveyed out of the mine by small rubber-tyred lorries. The 'spoil' was often used in the building or repairing of parapets.

The arrangement of a working shift was a matter of selection. A digger at the face, two men filling bags, trolley men (the number depending on the length of the haul), a bottom shaft man, two top shaft men, and the outside carriers, is a fair

example of the composition of a working party on 'spoil' alone. The helpers behind the digger, and sometimes the latter himself assisting, would place the timber sets.

Timber.—In the early stages of the war, and before the movements of our ships were severely hampered, much of the timber came from Norway. Later, Britain and France provided the majority. Recourse was had to every and all varieties. Planking, 3 x 9 in., was the standard size in most cases, although 2-in. material was also used. During times of shortage it was a *sauve qui peut* scramble, and these occasions during the first two years and a half were not uncommon. Very often timber was salved from demolished houses by the tunnellers, hand sawn, and utilised in the mines.

Ventilation.—Many gross infringements of the Coal Mines Act were perpetrated at the front, but there were few accidents through lack of air and these were caused by the effects of the afterdamp from our own or the enemy's 'blows.' The one-half and two-hour Salvus or Proto oxygen breathing apparatus were in general use for entry into mines when the air was considered vitiated, and the pulmoter was always ready in case of need. Officers and N.C.O.'s received special courses in the manipulation of these safety devices at schools instituted by the tunnelling companies.

If the atmosphere of a mine was suspected of vitiation, an officer or N.C.O. would don the Salvus or Proto, take his caged canary or white mouse in his hand and proceed to explore the mine with the aid of his air-tight electric flash-lamp. Should the canary or white mouse show signs of distress, the workers were not allowed to enter. On occasion, however, when immediate action had to be taken, and the air was bad, each man on the work was required to don an oxygen apparatus and retain it during the whole time he was engaged in the mine.

Some fairly elaborate blowers or fans were installed in certain sections of the front, but for distances up to, say, 500 feet, the ordinary 5-ft. blacksmith's bellows with 2-in. hose served all practical purposes. It had the great advantage of

being nearly noiseless and delivered a continuous flow. The bellows would be placed at or near the surface where the air was the purest. A 5-ft. bellows gave a discharge varying from 85 cubic feet per minute at the bellows' mouth to 11 cubic feet for a delivery 1,800 feet away. Should more air be required, more units of bellows could be called into service.

Listening.—I have referred previously to listening posts. Duty at a listening post underground was the tunneller's 'sentry-go,' and any dereliction on the part of the listener rendered him liable to very severe punishment. Should he fall asleep or be lax in other ways, the enemy might accomplish dire results, and for this reason special attention was given to the training of listeners, who, with experience, became so expert that the location of sounds could be placed to within a few feet. The nature and density of the soil in each mine had to be taken into consideration. Chalk would carry sounds which could be detected at distances of hundreds of feet, whereas the same kind and volume of sound might only be distinguishable in less than a quarter of that distance through sand. To detect the different sources of sound, such as picking at the face, walking, talking, trolley running, and the various ingenious ruses attempted by the enemy to outwit us, formed part of the listener's education and training.

Many apparatus to amplify the sound were experimented with. The electric listener was perhaps the highest development. It could be placed in a chamber near the mine entry and the leads extended to the most distant parts of the mine. This was useful in locating sounds from some far away point where a charge had been laid and tamped and was being held for future use or for a case of emergency. This instrument exaggerated the sound by means of accumulators. The intensity of sound could be registered, but the determination of the distances at which the enemy might be was not the same in all the soils. Although an excellent invention, it was found hardly practicable for the general use of the tunneller.

At the beginning, an ordinary water-bottle filled with water, to which was attached a stethescope, was found useful and from

this an advance was made when the French 'geophone' was evolved. This was in the form of a small round disc about 1½ inches thick, and 3 inches in diameter. (I am speaking only from memory). The sound-carrying medium was mercury upon which was placed a thin vulcanised rubber disc, which was affected according to the volume of sound, and transmitted the vibrations through sensitive terminals connected with the rubber tubes of a stethescope. This was in general use, as it was practical, easily carried about, and gave good results. It was used at the front listening posts.

Explosives.—After many tests with various well-known explosives, the tunnelling companies finally accepted ammonal as their standard explosive. It was found to be 3.6 times more powerful than black powder, and it combined in a medium capacity both the lifting power of the black powder and the shattering effect of gun-cotton. Ammonal had one serious disadvantage; it was most hygroscopic.

Charging.—This might be sub-divided into:—(1) Charges for 'camouflets;' (2) charges for 'cratering.'

'Camouflets' are undercharged mines, and such that all the destruction is done below ground without lifting the surface. Cylinders of galvanised sheet iron of diameters varying from 4 to 8 inches were filled with explosive, fused, fitted with leads, sealed, and kept in a convenient but safe place in the mine ready for instant use. These were called torpedoes. As before stated, holes were augered out from the listening post or mine faces, and should the listener report enemy sounds, one torpedo, or more, was brought up, placed in the bore-hole nearest to the enemy, the hole tamped, and the lead carried back to the exploder, which was probably at the surface or, at least, far enough from the face to provide for the safety of the operator. At such times an officer always lay at the face and continued listening. When it was thought that the enemy was in the best position for effective work, the watchers retired and reported, and the charge was blown. If possible, and unless the enemy drove directly upon our gallery or mine, it was advisable to allow

him to proceed until he had passed us. This gave us the opportunity of 'blowing' behind his working face, thus cutting off his retreat. I have in mind an occasion, and there were many similar occurrences, when we allowed the enemy to pass the end of our tunnels and proceed for a distance of 50 feet or more toward our front line. While he was thus progressing our men worked toward his gallery from a listening post, removing the dirt literally with their finger nails, their feet being swathed in sacking to eliminate any sounds while moving about. Talking was in whispers only. After removing a few feet of earth, the enemy's mine timbers were laid bare. The charge was then placed, the men removed, and the shot fired. In this case about fifty pounds of ammonal was used, and this broke down and caved 22 feet of the enemy's gallery. From the main gallery it was easy to gain access to the isolated portion of his tunnel.

After one of our 'blows' it was almost invariably the practice of the enemy to retaliate within from two to ten hours. But the blow would be of no effect upon our workings, for the reason that he would place his charge behind the caved portion of his own, thus retaining to himself all the damage. Why he did this was never satisfactorily explained, but as it was done for a purpose it must have been as a ruse or to break down further his tunnel so as to make it inaccessible to us in case we tunnelled around the edges of our own 'blow' for the purpose of entering his gallery behind. This latter feat had been undertaken successfully by us on previous occasions.

I have said that torpedoes were available for hostile surprises, but there were times when no torpedoes were at hand, and the tins of explosives themselves had then to be called into requisition. It was always desirable to tamp the gallery behind a 'camouflet.' This not only allowed the force of the explosion to be utilised against the enemy with greater effect, but afforded protection to our own workings. The enemy's mines have been entered and running fights have ensued in these cramped passages. Hair-raising are the tales, and all of them but add to the glory which is already the tunnellers'. But in such encounters, it was found convenient to have at hand a sort of mine easily

carried and quick in action. Accordingly small box-mines provided with handles were introduced—veritable infernal machines. Contact mines also came into existence so that our men had to be trained in the manner of searching for and cutting wire leads to any such devices, these wires, needless to say, having to be cut separately so as to avoid short-circuiting. Many and curious were the engines of destruction thus evolved through the ingenuity of the soulless headhunter; but all such sink into atomic insignificance at the mention of that arch-triumph of the gruesomely humourous tunneller, the mine—the deep mine—the real mine.

Set at perhaps 130 feet beneath the surface the huge charges of 30 or 40 tons of canned hell lie sleeping. Here one finds scope for the imagination. What a potential for destruction, and how to be likened to some huge monster. One can almost hear the rhythmic breathing, or sense the even heartbeats of this terror asleep. Harmless and docile, it lies unconscious in its earth-bound den, but let us prod the creature with a galvanic pole; stir him from slumber; arouse the demon into being—and behold the awakening. It is as though the beast snarled; opened wide its scaled eyes and jagged jaws; bellowed in red anger; crashed and slashed in gargantuan fury; then gathering itself in one tense, stupendous effort, belches forth from its cavernous maw all the fires and clamours of the seven hells, thunderous, vibrant, reverberate, while souls of men flounder in the unknown, the curse hardly silent on their lips and visage still distorted in sweating fear.

This, pedantic though it sounds, is the mine, the deep mine, the real mine. This, the supreme effort, the very superlative, the *raison d'etre*, of the tunneller. And here is his justice, the high, the middle and the low. So now we must enter into the cause of this vast commotion, this mighty upheaval.

Away at the end of the long gallery, which is driven under the heart of the enemy, a large chamber is excavated, or two or three as the case warrants. And in this chamber are placed serried rows of tins, one upon the other, each containing, say, fifty pounds of ammonal, until no space is left unfilled.

In placing detonators due regard had to be given to the capacity of the service explosive. Although designed to overcome a resistance of 100 ohms, yet it was not considered advisable to have the total resistance of the circuit more than 60 per cent of this. There might occur leakages or oxidation of the metal, and there were many other reasons why such a precaution was necessary. I might mention, however, that service explosives could be connected up in duplicate or multiple for overcoming the heavier resistances of huge mines.

In general, it was considered good practice to place a detonator, or detonators, attached to leads in every tenth tin of explosive, but should the mine be extremely large the number could be increased. Surrounding the attached detonators others were placed loosely in the explosive for further security against failures. Great care was exercised in sealing all the tins against the admission of moisture by waterproofing the cap-holes with resin, sealing wax, shellac, etc., and with soldering, for ammonal becomes inert if moisture is absorbed. It was best to solder all joints in the leads and then insulate them. Every precaution had to be taken, in other words, to ensure that the complete circuit was free from 'earthing,' or leakages of any kind, and the ammonal from water.

Series wiring was, in the end, found to be advantageous over parallel. Difficulty was found in balancing the circuits in parallel, and there was also a double chance of 'earthing.' Neither could the wiring in parallel overcome as great a resistance as in series. Three circuits in series were preferred for the sake of safety. The resistances to be reckoned with in a perfect circuit were (1) the resistance of the leads, (2) the resistance of the detonator. A Mark III detonator has a net resistance of 2.6 ohms. For large mines, $\frac{3}{8}$-inch four-cored armoured cable was used in the leads. It gave a resistance of .204 ohms per 100 feet of length.

The leads were carried back to the dugout or chamber selected for the position of the exploder. Precautions were taken by coiling the leads to prevent them from pulling on the

detonator and also on the joints in the leads themselves. They were also hung loosely from the gallery roof and sometimes encased to prevent displacement by the workers. Waterproof test-boxes and connection-boxes were set up in the mine and all terminals brought to them. Tests for continuity were made daily by means of the galvanometer, and, weekly, for total resistance, by means of the Wheatstone bridge. Tamping had often to be withdrawn in order to locate a leak or breakage in the line. When tamping was being placed it was necessary to safeguard against damaging or interfering with the leads.

Theoretically, tamping should be carried back from the charge along the gallery or galleries for one and a half times the least distance to the surface. To make absolutely sure, it was the rule to make it two, and in some cases, three times the distance. Tamping was accomplished by piling up filled sandbags along the gallery from floor to roof and filling all interstices with loose dirt. At intervals, air spaces to act as cushions were left between the solid tamping. Also, to prevent the whole timber lining of the tunnel from being pushed back, or askew, by the force of the 'blow,' sets would be removed here and there to break the continuity. All exploders had to be tested at intervals and especially just prior to a 'blow.' The exploder should be capable, when new, of fusing ¼-inch iridio-platinum wire of .0014 in. diameter through a resistance of 100 ohms.

Precautions.—Mention has been made of certain measures of precaution which had to be observed by the tunneller, for the common protection of all. In a mine there was always the necessity for carrying on work with the least amount of sound. From our own side we knew, by means of the geophone, that enemy sounds were transmissible, therefore we assumed that our noises were likewise a source of information to the 'Hun,' as well as of danger to ourselves. For this reason, and after we had detected underground indications of the enemy, everything was done to make our presence unknown to him. Conversation was carried on in whispers, feet were wrapped in sandbags, or encased in rubber boots, picking was done by the 'kicking' method whereby the digger sits in front of the face

with back propped, and presses his small, sharp-pointed shovel into the soil ahead of him with his feet, and then passes it out to the fillers behind. The rubbing noise of stiff clothes against the timbers had also to be avoided and all timber sets placed carefully, but without hammering. The swish of fresh air coming from the hose had also to be minimised. In short, the object to be attained was to make ourselves felt, not heard.

There were also surface indications which might give the enemy cause for suspicion, such as new blind trenches at the end of which might be a shaft or slope head, the dumps formed from newly excavated 'spoil,' or new built-up shaft heads appearing on the surface. Here the art of 'camouflage' was called into requisition, for the airman was a dangerous scout when travelling with his camera. Of course, certain ruses would be attempted on both sides, both underground and on the surface. Artificial sounds of picking, hammering, or walking could be reproduced by ingenious devices with the object of inducing a premature 'blow' by the other side. With practice our men were able to distinguish between the real and the artificial. Also there were such things as dummy shaft heads on the surface, toward which the enemy's fire was drawn, while the real works would be left in peace.

Aerial Photography.—Tomes could be written on the development and usefulness of this art in warfare, but I shall confine myself to remarking that we found it to be of valuable service in our work in noting craters, new hostile works, etc., and in allowing us to calculate the distance to coveted objectives.

Arrangement of Shifts.—The original establishment of a tunnelling company was 349 of all ranks. Early in the autumn of 1916 this was increased to 675. As this number gave but limited personnel to be scattered over extended works it was found necessary to add to it detachments of infantry, and some companies included on their rolls as many as 1,900 or 2,000 men.

The best arrangement, as found, was to divide the tunnellers themselves into five sections. Every two days a relief was sent

into the trenches, where it remained for six days, then returned to rest billets for four days; that is, six days *in* and four days *out*. The number of hours of continuous work in the mines was governed by the nature of the operations, from four to six being general.

I would like to have enlarged upon tunnelling at the front, and at times I have thought that perhaps the purposes served by this incomplete paper were not such as would prove sufficiently interesting or instructive. More interesting, I know, it would have been had I endeavoured to enumerate in anecdotal form the accomplishments of these first-line badgers, and more instructive, had I followed the more technical side.

However, recent duties undertaken by me have militated against any great elaboration—due to lack of opportunity—and I trust that those others among the overseas tunnelling fraternity, who might be induced on some future occasion to subscribe their knowledge and experiences to paper, and who have perhaps a better right to express themselves, will be more successful in their efforts, and that they will impart their story to the members of the Canadian Mining Institute in a more striking and fitting manner.

MINING IN CHALK ON THE WESTERN FRONT

With Some Notes on the Explosion of Large Charges of High Explosives

By Capt. L. B. Reynolds

(Annual Meeting, Montreal, March, 1919)

The Allies did not take the initiative in mining on the Western Front. Early in 1915 it was found that the 'Hun' was mining certain strong ridges in the Ypres sector, particularly around Hooge and Hill 60, and also in certain other portions of the line against the French. In each case he was attempting either to obtain possession of some dominating hill, or at least to work his way to observation points on the tops of the hills. So good a start did he obtain that at the beginning, in many cases, he attained his object; but his success was short-lived. Several tunnelling companies were hastily formed by the British and the French. The armies were combed for miners and mining engineers. Miners were recruited at the pits in England, given a week's training, and rushed to the front in France and Belgium, carrying a rifle, which they regarded with a mixture of pride and ignorance, appalling to behold. But these men were of the right stuff, and were later to show the 'Hun' that a man with the sporting instinct, engaged in a game into which he puts the hardest work of his life, is in every way the superior of the machine-made German soldier, as exemplified by the miners in their pioneer companies.

In order to give an idea of what underground warfare was like, it is first necessary to explain that there were two kinds: first, that which was waged in surface soil, where this was deep enough to carry on operations; second, that which was carried on in the chalk underlying the surface soil. The main difference between the two is that mining in the soil is silent, while mining in the chalk is necessarily noisy, and therefore requires different tactics. In Flanders and France, as far south as La Bassee, the line was in a country overlain by many feet of surface soils, principally clays. It was in this field that the Canadian Tunnel-

ling Companies did such heroic work and gained for the Canadian mining engineer that well-earned reputation for efficiency which was accorded him in the allied armies.

The company to which the writer had the honour to belong went south with the British army, and took over from the French a section of the line on the Somme. From the river Somme, which the lines crossed in a wide sweeping arc, the country undulated to a ridge overlooking the valley of the Ancre. Valleys ran at right angles to the river up to this ridge. In these valleys were our lines of communication, gun positions, etc. The front line handed over to us by the French was on the ridge along which, for three miles, the 'Hun' was reported to be mining at various points. The French had not a sufficient number of miners available to carry on operations at so many points on their front, as they were at that time being heavily attacked. Their efforts against the hated 'Bosche' were mostly limited to daring underground attacks on his advance to hold him temporarily, but their plan was to construct, eventually, a new line a little in rear, and thus nullify his months of work. Unfortunately, we could not adopt this procedure, as the crest of the hill had to be held at all costs. The 'handing over' by the over-worked French officers consisted of a trip along the front line, stopping at frequent intervals, entering a gallery, about 30 or 40 feet long, a dramatic gesture, and, "The 'Bosche' is there, Monsieur." "How far?" "Ah! dix ou douze metres, Monsieur. Je ne sais pas." The first week we were there the 'Bosche' let us know what he could do by blowing up our front line in three different places. We lost some men, and also any hazy idea that we were going to have a snap.

Night and day, all along that front, men lay with their ears to the ground, or against a convenient timber, in water-holes in 'no-man's-land,' listening here, there, and everywhere. Their reports were taken and positions mapped, and from these it became evident that the enemy had three main points of attack. The most dangerous and powerful of these was at the hill in front of Fricourt. A section of the company was therefore assigned to each of these fronts, and half of the section assigned

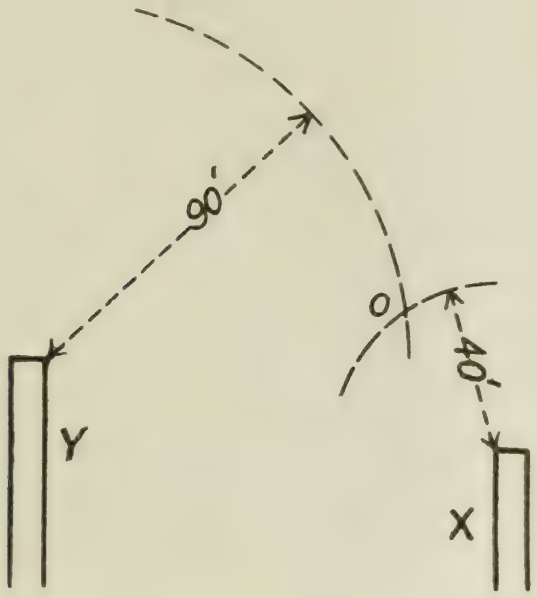
to the weakest point of attack, was used to reinforce that at the most dangerous. A company then comprised four sections, and a headquarter's staff of cook, blacksmith, drivers, clerks, etc. Each section comprised a captain, a lieutenant, two second lieutenants, 42 tunnellers, or skilled miners, who were the highest paid mechanics in the army, and 42 tunnellers' mates, who were mostly miners, but not necessarily so skilled. The whole was commanded by a major. It was soon found impossible for one company to do the work necessary to hold the hill, and later three more companies were assigned to each of the fronts, which first we had tried to hold with a single section.

It may be necessary here to explain how the position of the 'Bosche' was located, and just what is listened for. First, with the unaided ear, one listens for the sound of picking, then for the blows of a hammer on timber, and one judges by the loudness of these noises how close, or how far away, they are. Then, when the enemy's work is closer, one gets the faint sounds of the dirt falling from the pick as the miner works, the scraping of the shovel as he shovels up the muck, the peculiar, but easily distinguished, rumble of the truck as he trams it away, the thump of his boots in walking, or the scraping of filled sandbags as he drags them along, if he is doing that instead of tramming. The trained ear soon learns to recognise the different sounds, and when aided by instruments, such as were developed in 1916, these sounds can be heard for considerably greater distances.

The accompanying diagram illustrates the manner in which the enemy's works were located. A listener in the gallery *X* hears the enemy working at a face forward and to the left at a distance he judges as 40 feet. Another listener in *Y* hears the same work (and by synchronising watches they can both tabulate sounds and times to be sure they are listening to work at the same face) at a distance of, say, 90 feet to the right. Knowing the position of *X* and *Y* on our map, it is an easy matter to determine the point *O*, and it may be fairly certain that the enemy is working within a radius of 5 feet from that point.

Tables were drawn up detailing such information as "picking faint, so far" "plain, so far," "falling chalk, so far"

"dragging, walking, etc., so far." But each listener has to correct that table for his personal factor. As the enemy's gallery advances talking begins to be heard. The 'Hun' was very noisy, and given to shouting, which can be heard for a considerable distance, as compared with talking. By all these things one can 'keep tabs' on the enemy. Later, electric listeners were



installed on some fronts. The 'Hun' invariably used them, the officer taking his men's word and checking it by the electric instrument. By means of a resistance field, distances could be calculated exactly with these instruments, but their use was limited, as there were so many disturbing factors. The chalk after once being blown becomes broken and cracked for a considerable distance. At the centre of the 'blow' it is like cheese. The whole front is changed after a few blows, and the listener has to know the ground, its consistency, and sound carrying value before he can calculate distances accurately.

Let us suppose a report has been received of a hostile face being worked in a new territory. One listens in saps, in 'no-man's-land,' in the front line trench, in dugouts, in fact at any, and as many places as possible. The results obtained are

then plotted. The map shows the hostile face located within a small circle, let us say, 100 feet from the front line, and 30 feet below the surface. The advance of this face must be stopped, and the next consideration is, how many men are there available for the purpose, and how many men can the infantry supply to get rid of the spoil and help get up the timber, sandbags, etc. All these have to be carried probably 1,000 yards through communication and other trenches. These are the first factors, and they determine largely the nature of the defence to be made. An incline may be rushed out from the front trench to meet the enemy, and if plenty of men are available, a more permanent defence may be started further back. If men are scarce, it may be necessary to depend entirely on the incline, a procedure which is dangerous, especially if indistinct work is heard behind. When one gets within about 30 feet of the enemy he may stop working. Careful listening is now required. He may rig up a dummy pick and truck and if one rushes ahead confident that all is safe, because he thinks the enemy is still working and it will take him several hours to load, the result is likely to be a hurried call for the 'padre,' who will say a farewell service at the nearest safe spot. A new start will be made, and the game will go on.

As long as the enemy is really working, one is safe, and can push ahead by listening carefully. He may decide to 'blow,' and may hastily chamber out his gallery first, to a room big enough to hold his charge. Good listening will detect this as his work does not get nearer, and he usually uses more men. Then, if near enough, one can hear his men charging, which is accompanied by much walking, shuffling, thumping, etc. Word is now sent to the infantry in the trenches to cover that portion of the front from the sides and evacuate the front line, since it is our object to make the enemy blow, and not advance any further. The result of the blow is that the enemy has damaged his own galleries more than ours, as his were nearer the centre of the explosion. Air pumps are rushed in and, as soon as the area is free from gas, men begin work clearing the wrecked gallery to the point where it is completely smashed up. A new

gallery is then started off abruptly, and this is pushed with might and main. The men strip to the waist and dig for all they are worth, for now it is a race. The 'Hun' works by book, and timbers heavily. It takes more time to drive and timber his gallery, and his men do not work so hard. In nearly every instance when he blew, we could gain 20 to 50 feet on him, in the rush back to the old conditions. So gradually we drove him back, step by step, never blowing unless he refused to stop, but endeavouring always to force him to blow first.

All this may sound very simple, but unfortunately there was never the one face only, but several, all dangerous, and there were seldom men enough to go around. Most dangerous of all were the back galleries, coming up from the depths below, and necessitating back work to combat them. So strenuous was it in January and February of 1916, and so short of officers was our company, that although we were supposed to do six days in the trenches, and two days out, not an officer that was fit left the trenches during those two months for a longer time than to go down at night every week or ten days for a bath, and return by noon the next day. On a front of less than 1,000 yards, the enemy never made less than five 'blows' a week and once blew five times in two days. But never once, after the first month, did he get to the front line to kill any infantrymen, although our tunnellers, unfortunately, did not escape so lightly. But thanks to eternal vigilance, as well as guidance, our losses were relatively small, whereas on three occasions his front line was blown up badly, with great loss of life in one case. On July 1st the infantry attack at the opening of the battle of the Somme was preceded by the blowing of five great mines that wrecked his front line for a considerable distance and buried many of his machine-gunners, infantry and pioneers.

One bad feature of a mining front was that the trenches were always close together, and every night they would be wrecked by trench-mortar fire. Little presents like oil drums, with 100 lb. of high explosives in them, would be tossed across to mess things up. Showers of rifle grenades would keep one in good

training for the spring races, and teach football players new methods of dodging. Occasionally, the heavy trench-mortars would give one a few 200- and 300-lb. bombs, while the lighter varieties would throw over little rum jars, petrol tins and such missiles, full of high explosives. To live, one had to be an artful dodger in more than the ordinary sense of the term. No keener incentive is needed to make one recognise quickly when to run, when to stand still, and when to fall. One could usually see the beastly things wending their way in a tremendously high and greatly deceiving parabola. They were a factor which had to be reckoned with, since they meant wrecked top-works, entrances smashed in, and work held up, possibly at a critical moment. Supplies might not arrive, but be scattered along the way, causing endless trouble. In fact, we found from documents captured from the enemy that it was his regular custom, when pressed too hard underground, to order a heavy trench-mortar bombardment for the purpose of preventing the arrival of our timber and the disposal of the muck, thus delaying our work. All these were deciding factors.

The usual 'Hun' method of attack was to bring up two galleries at once, one being kept behind, and below, the other, or sometimes parallel galleries. He would work quietly and stealthily in the back gallery, and only when the front gallery was working and making lots of noise, so as to deceive us as to his real intentions. He would drive his front gallery as far as he dared, then blow it. At the same time he would have his lower back gallery face just up to the radius of rupture of his 'blow,' or to that point where it would just escape being smashed in. As soon as he would 'blow,' he would go in this back face and work as hard as he could to get below us. Woe betide those who failed to 'spot' his tactics, and had not taken similar means to meet them. This entailed deeper and deeper mining. At the time of the battle of the Somme our shafts had reached a depth of 146 feet vertically, and we discovered, when we investigated the 'Hun' positions which we captured, that he was coming up with a great incline several hundred feet in length, which already equalled a depth, at the collar of our shafts, of 212 feet.

Some distance behind the lines, he had a power station with three gasoline-driven electric generators. From these he operated small hoists and lighted his galleries with electric lamps. This solved one mystery as to how he got rid of his gas so quickly and was back at work while we were still pumping in air to remove the gas. We used the bellows with 1½-in. air hose at first, but they made too much noise, and took up too much room. They were useful to supply fresh air to a carbon dioxide laden atmosphere, but were no good when the deadly carbon monoxide from the powder was encountered. Next we obtained Hollman pumps with 3-in. air hose. These were a great improvement, but there was a large amount of slip in these pumps, and it was necessary to work them with a fast jerky stroke, which soon racked them, and it was very difficult to keep the 'Tommies' at it. We also had rotary hand-blowers, but they were very noisy, took up plenty of room, and so were not of much use.

All our muck was hoisted on wooden jack-rolls, made on the ground. We built these 12 x 14 in. in diameter, with double drums for our deep shafts, and with a handle at each end, two men on a handle. A double relief was necessary for each pull. The 'muck' was put in sandbags, two of which were placed at one time in a running noose, and hoisted up with a light wire cable. On the shorter hoists Manilla rope was used. In an incline, the hoist was at the bottom, the rope working over a pulley at the top; in a vertical shaft it was at, or near, the surface. The later plan was to cut a station at sufficient depth to be safe from the heaviest trench-mortars, and to run up from this station two or more incline entrances. Single compartment shafts were 3 x 6 feet; double compartments were 6 x 4 feet for vertical, and 60° shafts were 3½ x 4 feet. The galleries were 4 x 2 feet, for fighting galleries, and 4½ x 3 feet, for back galleries. The best incline was one with a slope between 1 in 2 and 1 in 3.

After a 'blow' immense quantities of carbon monoxide were formed. This would be blown into the chalk, and in working in the region of an old 'blow' it was constantly encountered. Canaries were used as detectors. The bird would get a mild

'jag' first, and become very lively; then, as the gas became denser, he would drop over, and turn his legs up. It was time to get out quickly when this occurred. How many lives these little birds saved is hard to say, but the number would run into the hundreds. They used to 'do' their six days in the trenches, and six days out, with more regularity than the average infantryman. The explosive we used was ammonal; it is 3.6 times as strong as gunpowder, easy to handle, easy to charge, and gives a terrific result. The first lot we obtained was sent out on an absolute guarantee, backed by the War Office, to make no gas. How many of you have bought powder with that sort of guarantee? Well, the result was the same, only that they had failed to mention that the gas, if any, would be carbon monoxide. After the first mine was set off, an officer and a corporal went below to investigate the damage done to our own galleries. They did not come back. The sergeant went down with a man to see what had happened to them; they did not come back. A call was sent to headquarters, and another officer and a man went down, and so it went on until finally twelve were dead. Similar experiences by one or two other companies did not, however, convince the War Office, or the powder companies, for they then said the powder must have been wet, or must have been mishandled in some way.

Life saving stations, with Salvus and Proto oxygen breathing apparatus were installed, and reviving sets, with several cylinders of oxygen were kept at some safe and convenient spot in the trenches for rescue work. But the deadly cumulative effects of a slow carbon monoxide poisoning take a long time to get rid of, and are even worse, in the long run, than a single dose sufficient to make one unconscious. Against this there was no defence possible, and the majority of those who were engaged in mining in chalk regions suffer from the effects of this slow poisoning today. The Salvus apparatus had only one oxygen cylinder, and was very useful in a gassy atmosphere for investigations of about twenty to thirty minutes duration, but for anything longer than that the Proto is much the better apparatus.

We now come to some particulars concerning explosives that will probably be of practical interest to the members of the Institute. I may say that we owe much to the French for working out the formulae, and discovering the effects, of high explosives. With true British insularity and caution we re-tested these formulae before accepting them *in toto*. These formulae had in great part been worked out before the war, but the factors necessary for the different chalks, clays, and soils, as supplied by the French, were found to be reliable.

Let us suppose that it becomes necessary to destroy an enemy gallery, as at *O*, for example, in the preceding diagram, working from *X*. Knowing the distance and the nature of the intervening ground, it is possible, using the appropriate formula, to calculate the exact charge necessary. One then loads that charge, packing it tightly in the face, and placing in it two rubber bags, containing the detonators, with electric wires leading therefrom. The charge is then tamped. This is done for two reasons: first, to confine the gas of the explosion, and second, to save one's own works from destruction caused by the back firing of the charge. When a large body of high explosive is fired, there is first an instantaneous shock, and a chamber of compression is formed. This first shock is followed by a release of gas, which causes a rupture of the ground, and if sufficiently great will break the surface. In a 'camouflet,' or a mine that does not break the surface, the effect is spherical if the ground is homogeneous.

With the formation of the chamber of compression, there is also formed a spherical area of rupture in which any working, of whatever type, is absolutely destroyed, and surrounding that an area in which an untimbered gallery would be able to exist, although it would probably need considerable repairs. These same areas are also formed when a mine is blown. What is hard to grasp is that in the detonation of high explosives all the damage underground is done during that first period of the

formation of the chamber of compression. The shock of this first explosion racks the galleries and ruptures the formation. The escape of the gases, expanding by heat in the chamber after its formation, gives the rending effect and the slow mighty upheaval that does the damage to the surface and within the area of the inverted cone from the charge to the surface.

Tamping is necessary to get the full effect of this second action, and to prevent it from being exerted on one's own gallery. The usual and safest method was to tamp a distance at least equal to the distance below the surface. To take a typical case, there would be tamping 15 feet, air space 10 feet, tamping 10 feet, and air space 10 feet (total 45 feet), for a mine 50 feet below the surface.

Contrary to general previous opinion, it was also found that in detonating these large charges in a dry gallery, numerous detonators are neither necessary nor desirable. One large detonating charge is much more effective. In warfare two are always used, as accidents, such as the enemy 'blowing,' may happen and give trouble. In chalk mining the smallest charge used was about 2,000 lb., the average 5,000 lb., with charges of 10,000 to 15,000 lb. for offensive work. In these large charges one large powerful detonating charge will set off the whole charge instantaneously. This was well illustrated in the firing of wombat drill holes in the making of trenches during a battle. The holes were previously drilled under 'no-man's-land' about 7 feet below the surface and kept as flat as possible. They were drilled for the most part from the underground saps, which had been run to within, say, 150 feet, of the German trenches. The holes were loaded with tin torpedoes 5½ inches in diameter, holding 9 to 10 lb. of high explosive per running foot. In a hole 7 feet below the surface these would blow a trench about 5 feet deep, when a large detonating charge was placed in the far end. When detonators were placed in each torpedo no difference was observed, except that in places the trench

would be deeper than at other places, and a wavy effect obtained. This was not desirable. When several detonators were placed at intervals of 10 yards and fired simultaneously this wavy effect was more pronounced. As we always wanted the trench to be deepest at the enemy's line, and also wished to do the most damage there, we placed our detonating charge at that end. But the result of the experiments clearly showed that a large powerful detonating charge gives a far more uniform result than is obtained when numerous detonators are used.

On several occasions I have unloaded enemy mines and found that he had two methods of detonating. His explosive 'Westphalite' was put up in 20-kilo metal boxes. He had in each box two holes, each of which held a block of T.N.T., into which he inserted detonators. In one mine which he had intended to blow at a cross road when he retreated, I found 84 boxes of 'Westphalite' with 146 detonators, some of the boxes having only one detonator. In the centre he had a 50-kilo box of 'Freibergite,' a powder put up in packages having about the same cross-section as an ordinary brick, but twice as long. He had removed part of this and replaced it with about 20 pounds of T.N.T., putting several fulminate caps in the latter, and in the centre, a steel detonator about 8 inches long and 1 inch in diameter. The firing of this mine was arranged for by pulling out a pin, which he had done. The removal of this pin allows acid to come in contact with a thin metal disc and when the acid eats through this disc it comes in contact with fulminate of mercury, and detonates the charge. By regulating the thickness of the metal and the strength of the acid, he could time the charge to go off in a day or in three months. This particular detonator was removed at 5 o'clock one afternoon, at least two weeks after he had left it, and it went off at 3 o'clock the following afternoon. I remember being frightfully 'fed up' because I had to carry it about three miles to where it could be placed under observation to see when it would go off. Another method was to have the acid eat through a wire which released a spring,

the thickness of the wire regulating the time. In mine warfare, his usual method (which was ours also) was to use electric detonators. Occasionally he used fuse, but very seldom.

By using direct down holes into homogeneous rock, loading these holes with the same charge, and different powders, measuring the width and the depth, and using just sufficient powder to barely break the ground, the miner can calibrate the powder to the ground. This is a very simple and effective method for comparing high explosives, and by its use the miner can select from different powders the one most suitable to the ground.

TUNNELLING REMINISCENCES

By Major A. W. Davis

(Western Branch, Nanaimo and Nelson Meetings, June, 1919)

It is hoped that the following notes on certain phases of the defensive and offensive mining operations on the Western Front may prove of interest. As my experiences, both with the Imperial and Canadian Tunnelling Companies, were confined to the operations in the clay areas, these are here given chief emphasis, although the operations in the chalk, less extensively referred to, were no less important.

On the Western Front the clay area extended from north of Ypres to considerably south of Armentieres. Practically all the mining carried on to the south of this town was in chalk, and a different method of work was consequently necessary. In the clay area, secrecy and the driving of galleries without detection by the enemy were the governing factors, but in the chalk area, where the pick had to be used, these results were unobtainable, and the general plan was to drive a number of galleries, trusting that some of them would get through. The noise made in driving certain of these would often confuse the enemy as to the true location of others. After a 'blow', however, whether by the enemy or ourselves, galleries would often be driven in again quickly before the enemy had a chance to get back to the same area himself. In this case, even in clay areas, no attempt would be made at secrecy. Of course, in ground previously broken, galleries could often be driven or recovered with very little noise. Normally, in the chalk, to keep the sound of work from the enemy was impossible, and not attempted. The old 'dodge' of working at a spare face, until the actual moment of 'springing' a mine, was often resorted to. Mechanical picks were also used at times.

The first mine, of which I have knowledge, was blown by the French at Hill 60, near Ypres, in the winter of 1914-1915. I remember one crater which we called the 'French Crater,' and there was also an extremely small gallery that had been driven

by the French and had to be negotiated on hands and knees. This was called the 'French Gallery.' The French mine just referred to was a very shallow one.

On April 1st, 1915, the British blew six mines at Hill 60. Gunpowder was used, and the charges averaged about 1,000 pounds each. These were considered very large charges at that time, and were blown at a depth of about 25 feet. From the resulting operations, Hill 60 was taken by the British, but lost on May 1st, when the enemy made a gas attack and retook the ground they had lost a month before.

On Sept. 25th, 1915, the British blew a mine at Railway Wood, north of Hooge; they had also blown one previously at Hooge itself. At Railway Wood the charge was 7,000 pounds of gunpowder and the depth was about 40 feet. As clay practically reached the surface at this point and there was no running sand, any depth was possible. From this time onward, the depth and size of the mines gradually increased. Gunpowder was superseded by ammonal, which was much more powerful, more compact and safer. This is a T.N.T. ammonium nitrate explosive; its composition is T.N.T. 15 per cent, ammonium nitrate 65 per cent, charcoal 3 per cent, fine aluminium 1 per cent, and coarse aluminium 16 per cent.

As all big charges were fired electrically, the wires leading to them were tested daily for resistance, and any close circuiting or breaks were therefore at once detected. Calculations as to the horizontal and vertical radii of rupture for various soils and depths were also carefully calculated, and one could tell with fair accuracy what the result of an explosion would be.

At St. Eloi and the 'Bluff' and all the way down to 'Ploegstreet' Wood, just north of Armentieres, active mining was continued on a gradually increasing scale. This era of mining in the clay area culminated in the attack of June 7th, 1917, on the Messines Ridge, when about seventeen mines were blown on a front extending from 'Ploegstreet' Wood to Hill 60, nearly 10 miles long. These mines averaged in depth from 70 to well over 100 feet, and each carried from 40,000 to over 100,000

pounds of ammonal. Some of the craters were enormous; that at Spanbroeckmolen being over 300 feet wide and from 50 to 60 feet deep. In a few cases, the craters were shallow, due either to slight undercharging or a possible deterioration of the charges, some of which had lain in place for a year.

The Imperial and the Colonial Tunnelling Companies, with the passing of time did more and more work for the infantry, such as making deep dugouts, subways, tunnelled machine gun emplacements, etc. In fact, before June, 1917, the bulk of the work done by the companies was no longer mining, offensive or defensive, but that just mentioned.

The first drafts of men for the Imperial companies were largely from the North of England. These men were sent over in a hurry, and although many of them had practically no infantry training, they acquitted themselves well. They were keen and conscientious and had their hearts in the work; the footages they consistently made underground, often in extremely bad air and in danger of being blown up, were remarkable. Everyone was willing to take a chance. A number of these men were middle-aged, and a great many were deeply religious. I remember a corporal, Humphries, afterwards killed; a man with a son in the army. This N.C.O. had held responsible positions in the coal mining districts of northern England. No man could have been more efficient than he, and there were many of his type. At this time, the spring of 1915, I may state that I was attached to an Imperial company.

Over most of the clay area the surface soil covered the clay proper for a depth of from a few feet to as much as 60 feet or more. Lying on top of the clay there was usually a layer of running sand, which was really a layer of the surface soil saturated with water. Where the clay was not very near the surface, all the original mining was limited in depth to the top of this running sand. No one, using ordinary timber, was able to get through it. The enemy was likewise limited as to depth, and where this condition prevailed, the protection of a position was easy, as he could not get in below us—the fighting took place on one horizontal plane as it were.

Appliances gradually improved, and on our side we introduced the use of circular steel rings, which were taken up to the line in sections which could easily be carried. These sections were then bolted together and 'jacked' down through the bad ground. The maximum of bad ground gone through in this way was about 70 feet. This was in front of Messines, where three different sizes of this 'tubbing,' as it was called, were used, beginning with the largest. Very often only a few feet of bad ground was encountered, and then timbering would be resumed after getting again into the hard clay.

Some of the early attempts at shaft sinking through bad ground, with little material available, were rather amusing. Someone would sink a shaft about 7 feet square, using timber spiling. The intention would be to commence an internal shaft when the bottom of the original spiling was reached and so carry on, repeating the process until good ground was reached. The usual result was a hole at the bottom of a shaft about 1½ feet square. The mud and running sand also had a tendency to boil up at intervals, with the result that the shaft house would sink and collapse.

Early in 1915 most of the listening for hostile working sounds was done by ear only. Homemade listening apparatus, usually a French soldier's water-bottle with tube and ear-piece attached, was the only listening device available, but at the beginning of 1916 a good listening apparatus was issued to us and used by most of the listeners underground. This apparatus, called the 'geophone,' was a disc about 4 inches in diameter and about 1½ inches thick—it resembled a hockey 'puck' more than anything else—with either one or two rubber tubes connecting it to ear-pieces. It would 'pick up' the enemy's ordinary working sounds 100 feet away and locate their direction as well. It had one big advantage over the electrical instruments used by the enemy in that the sounds heard were not distorted. It was easier, when using the 'geophone' to recognize the different sounds, and after a little practice, good listeners could distinguish, at a distance far beyond the range of the naked ear, the dragging of sandbags, falling earth, spade work, footsteps, etc.

By using the bayonet to excavate the ground and catching the dirt before it fell, we were enabled on various occasions to tunnel close up to where the enemy's workings had been located, and to do this in spite of his listening apparatus. Great care was necessary in work of this sort, as one careless man could easily ruin the success of such an enterprise and cause numerous casualties among our men as well.

Apart from the large charges, already referred to in connection with offensive mining, 'camouflets' were repeatedly blown for defensive purposes. These are mines blown underground with the object of wrecking an adjoining hostile gallery or working of any kind. Technically a "camouflet' does not break through to the surface, although many of ours did. The original plan in connection with 'camouflets' favoured very small charges, of 50 or 100 pounds of ammonal, usually placed in bore holes. As the enemy used light charges as well, no great harm was done on either side. A more aggressive policy was gradually developed, and as a result, 'camouflets' of several thousand pounds of ammonal were blown, the limit in size depending on the amount of our own workings which we could afford to wreck and our depth below the surface. An ideal example of this type of 'camouflet,' as opposed to that used in the original purely local fighting, was blown at the 'Bluff.' Here, our tunnellers (on this occasion the 1st Canadian Tunnelling Co., under Major North), working at great depth got in behind the enemy's workings and with one heavy 'blow' cut off completely a shallower hostile gallery system aggregating 700 feet or more of galleries. Our tunnellers afterwards broke into this system and found it occupied with the bodies of German miners who had died at their work. Some of them lay close to the wrecked ground and had evidently been engaged in trying to dig through the wrecked area when overcome. Gas from the explosion probably killed the entire party.

On another occasion, one of our long offensive galleries was blown in by the enemy, who, by the way, had also developed a new scheme for protecting a front where he knew we were mining. This consisted in blowing a number of large mines from his

galleries lying below 'no-man's-land'. The idea was that the area of rupture of these mines would include any gallery of ours in the vicinity crossing over to his lines. The gallery of ours, referred to above, was wrecked by one of these mines. Thirteen men were at or near the face, which was well under the enemy's trenches. Our men outside, working night and day at top speed, got through about 200 feet of wrecked and completely closed-in gallery in ten days. They found one man alive; the rest had died. The way in which this man was kept alive was interesting. The gallery extended towards the enemy's support lines and the men who died had waited at the wrecked end (the nearest point to our lines). This man stayed at the face and the grade of the tunnel was such that the point he occupied was 20 feet or so higher than where his companions lay. They all died, it is supposed, of CO_2 poisoning, but apparently this heavy gas had not reached him and he got out alive, although his chances must have seemed infinitesimal. He was given a rest in England and deserved it after his experience.

When mining was first begun on the Western Front, all shafts were sunk in the front line. Here they were subject to raids, and the shaft heads were constantly being 'done in' by shell fire. In connection with the chief offensive operations and for later defensive work, shafts were sunk well to the rear (sometimes as far back as 200 or 300 yards), in out-of-the-way places. Special steps were taken, also, to conceal both the shafts and the 'spoil' coming from them. Sometimes trench railways ran by these points, facilitating the transport of supplies, and the removal of the 'spoil.' At one mine a small Sullivan air compressor, operated by a gasoline engine, was hidden away in a fairly deep dugout that muffled the sound. At a great many places we had dynamos and motors, the former operated by gasoline engines. The enemy had similar installations, as we captured large amounts of equipment of this kind after successful attacks.

Ruses of various kinds were attempted during operations underground. The enemy was the first, I believe, to begin picking up signal messages by induction. At one of our mines,

for some time, 'fake' messages relating to our mining operations were sent to headquarters by a front line circuit, for the enemy's benefit. For instance, after one of his 'blows' we would wire back that our workings were 'done in', when as a matter of fact they were not. It is believed that on more than one occasion this ruse bore good results. At another time, an officer, just before tamping a charge, took a shovel and pounded away with it on the face of the gallery. The enemy's workings were practically alongside, and his intention, as he explained it, was to have the German officer down listening when the charge went off. The result of this particular 'experiment' will never be known. It is a rather dangerous undertaking if one has much tamping to do.

The tunnelling companies, Imperial and Colonial, have many stories of adventures underground. The officers are, and were even more so at the beginning of the war, a most cosmopolitan set. In one mess I have seen men from China, Burma, Australia, South Africa, South America, Canada, and England.

INDUSTRY, DEMOCRACY AND EDUCATION*

By C. V. Corless

We are living at a period of world history in which social phenomena are on so vast a scale, are of so profoundly soul-searching a nature and are occurring in such rapid succession, in the great world drama in which we are both actors and spectators, that, in our efforts to obtain a rational point of view in relation to them, our minds may fail to discern the simple in the complex, and our understanding is liable to become confused or even overwhelmed. To the social student whose scientific training has convinced him of the truth of the evolutionary law, *Natura non facit saltum*, it is neither the vast scale of the events, their deeply soul-stirring nature, nor their rapid succession that matters so much, as the discovery of the underlying principle or law in accordance with which the disintegration and reintegration, which are the two aspects of social evolution, or indeed of evolution everywhere, are occurring. He is most deeply concerned in seeking an answer to the question, Have we, in the present great and perplexing upheavals in human society, whether regarded in Central Europe, in Russia, in Great Britain or in America, a really new cause at work, or, have we, though on a very large scale, merely new manifestations of the working out of an old principle?

When we think of the appalling struggle in Europe, into which the world's greatest exemplar of democracy was finally drawn, no one has any hesitation in admitting that the great conflict was fundamentally a life-and-death struggle for self-preservation and self-propagation, on the part of autocracy. The variations we meet with in statement of the cause of the war arise mainly from differing distances of perspective. But in the last analysis all agree that the autocratic system of political government, which found its very soul and centre in Prussian despotism, was consciously arrayed in a final 'world-power-or-downfall' struggle against a love of freedom which was steadily widening and

* An address at the joint session of the A. I. M. M. E. and C. M. I. at the Annual Meeting of the former society, in New York, on February 18th, 1919.

deepening throughout the world, and particularly throughout those parts of the world where this love of freedom and justice has found expression in democratic institutions. It is not irrelevant to our discussion to recall in passing that this most imposing structure ever conceived by the human mind as an instrument of tyranny is lying today an irretrievable mass of ruins, completely overthrown by the eternal and irresistible power of freedom, justice and right, which it affected to despise.

If again we regard the social turmoil in Russia, the cause is at first not so clear. Hunger, deep and widespread ignorance, the misfortunes of war, and German and Bolshevistic treachery have plunged this hapless people into the abyss of anarchy. But we need carry our minds backward only a few months in order to pick up the thread which the Russian people attempted gropingly to follow, but which their ignorance, their economic disorganization and the treachery of interested factions caused them so easily to lose. For democracy is a form of government suitable not for the lowest, but only for the highest, type of civilization. It can succeed only when it is based on intelligence and when it arises from an inherent love of freedom and a deep respect for law and order.

When next we regard the widespread social, and particularly economic, unrest in Great Britain and in America, which centres chiefly around the antagonism between capital and labour, we find the real cause disguised by divers names for corresponding phases of the discontent. Now the conflict centres on wages, then on hours, on holidays, on the right of dismissal, on this working condition or on that, on recognition of the labour union, or on some one of a variety of other causes of friction. But those who have experience know that to increase wages, to shorten hours, to improve now this working condition and now that, or to concede any other of the varied demands of labour, never satisfies. The discontent of labour only deepens from month to month. It is not low wages, or bad working conditions, or long hours, or want of holidays, or of other concessions, or any or all of these complaints, taken singly or together, that constitute the real grievance of labour and that form the basic

cause of the continual strife which frequently culminates in trials of strength or endurance. To grant any or all of these does not give any assurance of cessation of demands or of permanent improvement in the relations between capital and labour.

What then is the essence of this seemingly endless difference? What is the underlying cause of the great industrial unrest? What is the principle for which (though perhaps labour itself, or even capital, may not always recognize it clearly) the contest is in reality continually being waged? There are probably very few men who would not be willing to earn less, to work harder and for longer hours and under worse conditions, or to get on with fewer holidays if it were done for themselves in any undertaking in which they really felt a deep personal interest. But, in modern industry, they do not feel personally interested. They have no sense of ownership. They never begin and finish anything. They have little or no interest in the end product. They do not have the opportunity to think for themselves. They are generally required to perform certain definite work, or even mere mechanical movements, without consultation, or in a way that does not call for reasonable exercise or recognition of their intelligence. They have very little, if any, sense of personal responsibility. They have little or no voice in governing themselves. They are parts of an organization, cogs in an economic machine, which they do not fully understand, and in which they almost lose their identity, that is, their freedom for self-development. Somebody, somewhere, shapes the organization and sets it in motion, but the part of the organization they see or of the work they perform usually has little, if any, scientific or social meaning to them. Hence their spirit rebels. The human spirit, unless it has been utterly suppressed, is fortunately so constituted that it always rebels against any form of external authority in which it has no share and which it does not intelligently grasp.

This deep love of real freedom is one of the most distinguishing characteristics of the human spirit and lies at the very heart of all human progress. It is one of those basic differ-

ences that distinguish man from every other creature of the kingdom to which belongs also his long line of lowly ancestors. With almost infinite patience exercised throughout eons of time, Nature gradually fashioned an ascending line of beings with a central nervous organ, endowed with mind, which enabled them to free themselves more and more from the trammels of their physical environment. These beings, gradually becoming more clearly conscious, intelligent, and human, and progressing correspondingly in their freedom, in their gradual ascent to full human status finally reached the problem of primitive man's relationships in association with his fellows. In the course of the many succeeding eras which constitute the period of human history, man has gradually evolved the democratic principle, which has arisen from his growing consciousness that the highest degree of freedom can be attained only in co-operation and which is deeply rooted in the ethics of this human association. Gradually, with many struggles and infinite discussion, with occasional set-backs but general progress, with general evolution but occasional revolution, man, where most highly civilized, has thus won for himself democratic freedom in certain aspects of his relationships to his fellows, which we group broadly as political and municipal associations. What we need now to recognize clearly, is, that this historic struggle for democratic freedom in political and municipal affairs, which has deep hereditary roots in the long pre-historic struggle for more purely physical freedom, is, under one disguise or another, now spreading over into this new field and is becoming a struggle for self-government in industry. If we would grasp the real inwardness and true proportions of the industrial problem, it is necessary for us to lift it out of the muck and mire of recurring squabbles over this and that petty difference between the parties in industry and to place the whole issue on a higher plane. When a great principle is at stake, a principle that has been inherent in creation since the very beginning of animal life, a principle that has divided and shaken, and is at the present moment dividing and shaking, the world of man, to its very foundations, surely it is time we took the trouble to grasp it clearly, surely it is time we ceased playing and jockeying with

the issues raised by it and, like men of full mental stature, frankly recognized it and deliberately so shaped our conduct as to accord with it. Evasion, under such circumstances, is senseless. What is needed is clear and fearless thought, decision and resolution. It is not sufficient excuse that we cannot clearly see all the details of our future progress. In this matter, we may well take a lesson from President Wilson in dealing with the principle of the "League of Nations." We should clearly and fearlessly grasp and stick to the principle, knowing that errors in detail will be more easily corrected than failure in principle.

The sooner we recognize this single, simple principle as the root cause of the existing industrial antagonism, just so much the sooner shall we begin to work intelligently toward a permanent solution of the problem which faces us in the continual, but often clouded, struggle between capital and labour. Any step taken in clear recognition of this will be a step nearer the real solution of the problem. Other steps may be taken from the best of motives, they may be based on the most humane feelings, they may be fully justified and worthy of the highest commendation, but if they do not in some way conduce to this end, they will not assist in effecting a final solution of this great industrial problem. It is better for us to take time to see the goal clearly. Then we shall be able to judge intelligently as to our progress toward it. Society has abolished open slavery of all kinds. America did this at enormous cost in blood and treasure. The difficult problem now is, gradually and with as little economic confusion as possible, to abolish every other form and semblance of autocratic rule. Industry must now gradually come to be ruled by the intelligent consent and approval of all the interested parties. Industrial unrest will continue and will increase until society recognizes this and takes such steps as will secure suitable organization and sufficient general economic intelligence to effect it. We cannot stop half way. Democracy will not be content with mere political and municipal control. It will never leave the matters that affect most deeply and intimately our very existence and manner of life, to the

autocratic decisions of a few, no matter how worthy or how intelligent they may be.

England already recognizes this and, as all are now fully aware, has, under the "Whitley Scheme," of which I gave a brief preliminary account before the Canadian Mining Institute last spring, adopted the idea as a government policy. Her industries, in particular those most highly organized on the side of both capital and labour, are being organized under this scheme. Many joint industrial councils are already formed. No doubt in the United States, as certainly in Canada, the organization and the working out of the functions of these will be watched with the greatest interest. This government recognition of the principle of representation of the governed in industrial relations is a first, but an enormous, step in the right direction.

A fair and proper sharing in the control of industry among the several co-operating factors will gradually bring about that feeling of interest and responsibility and that just division of the joint product among the interested parties, which will restore the incentive to do one's best and will make industry once more, as it should always have remained, the handmaid of human welfare. Industry, properly conceived, is not something to seek to run away from as long and as frequently as possible, for holidays. Work, done under proper conditions and with the right attitude of mind, can be made so mentally stimulating as to yield very real pleasures of its own. When it does thus stimulate interest and thought, it ceases to be drudgery and no longer fills the mind of the worker with envy and bitterness. When a man has reason to take deep interest and pride in his work because he, jointly with others, contributes his energy and intelligence to a common result or product in which he is interested and in which he is convinced he will have a just share, he will cease to watch the clock and will experience some of the real joy of work of which we hear so much. We need only analyse our own experiences to realize the truth of this. Any doubts we may have as to the exact truth of this probably arise from our daily experience with men whose independence and self-respect have been, in part at least, lost, owing to long years

of domination by our existing industrial system. Probably the most pernicious defect of the existing system is this gradual undermining of the workmen's personal responsibility, interest, and self-respect, which are so essential to the development of personality and character.

The British machinery appears to be based on the right principle. The joint industrial councils (of national scope in each industry), the district councils, and the shop committees, are based on equal representation of capital and labour. That (as in the case of any other new machinery) experience in its operation will prove considerable modification, adaptation, and adjustment to be necessary, is to be expected. And that difficulties will arise from time to time, particularly in the less organized or wholly unorganized industries, is a practical certainty. But, if machinery is designed on the right fundamental principle, such alteration and adaptation merely indicate progress and are easy. If designed on the wrong principle, the more the machinery is perfected the deeper are we plunged into the original error.

There can be little doubt that in recognizing the representative, or democratic, principle in industry and in adopting this principle as the basis of a national industrial policy, Great Britain has started on the right track. It is peculiarly appropriate that England, the mother of parliaments as well as of the modern industrial system, should now take the lead in introducing the parliamentary idea into the organizations for controlling industrial relations, as a principle of national economic reconstruction. But let no one confuse starting in the right direction with completing the journey; creating machinery, with carrying out the work the machinery was designed to accomplish. The journey is only begun and it promises to be very long and beset with many difficulties. The history of political democracy should warn us of this. The work to be performed by this new machinery will be vast in amount. Though it will, if it gradually removes the deep cause of the present antagonism and thus restores a high efficiency in industry, be the means of adding greatly to the national wealth, contentment, happiness and

prosperity, yet, because it will surely affect the distribution of wealth, it may ultimately mean serious apparent economic loss to many individuals. All the more does society need once for all to assure itself that the underlying principle it is adopting is right and just to all.

Has any one any doubt of this ? Has it ever proven to be true that any people, or any section of any people, can safely entrust any aspect of their progress and well-being to any other people or class ? Has it ever proven otherwise than that both parties were injured ? Have you any knowledge of any instance which did not tend toward moral degeneration of both sides of such an arrangement ? Do not present industrial relations further illustrate the truth of this ? Have we not all some experience of the moral degeneracy that has resulted in industry from failure to recognize this principle ?

Our industrial machines have been turning out two products. We have so far intently regarded the one and largely neglected the other. But the human product, which has been largely neglected, is of infinitely greater importance than the material product. Our aim has been so to beneficiate the material entering our plant that it may be of increased economic value when it leaves the plant. But, if we do this at the cost of shrinkage in value of the personality of those operating the plant, where is to be the recompense ? Can this loss justly be compensated by wages, or by dividends paid to someone else ? Do you know of any conditions under which human personality does not deteriorate, except those of freedom ? Does the present method of organizing industry by a few, generally without consultation with or representation of the many others who are intimately concerned in it, secure this feeling of freedom ? I believe that all morally just and honest men, who will take the trouble to think out the fundamental issues of this industrial question with sufficient clearness to grasp the principle involved, will readily admit the justice and rightness of the general principle on which the Whitley Scheme, adopted as a labour policy by the British Government, is based.

If this opinion is right, if the democratization of industry is the principle from which all real progress in adjusting industrial relations must start, then we can hardly dwell on this matter too long or too thoroughly. It is necessary to saturate our minds with it so thoroughly that it will gradually change our habits of thought and action, that it will permeate all our views and change all our attitudes and feelings towards our fellow men in industry. When we have thus become thorough converts to this view, there will be some hope that organization to give effect to it may have a chance of success. Not otherwise. This is at bottom essentially an ethical question. If democratic organization is not based on conviction, it will, I fear, prove to be a form without spirit. But it is further necessary that we seek to propagate this view as widely as possible. For these principles cannot be carried out by individual firms with complete success. Economic organization is no longer local. In very few respects is it even national. More and more is it becoming cosmopolitan. Hence we should avail ourselves of every opportunity to discuss this question publicly. And it is even more necessary that we should, in our capacity as citizens, give voice to the demand that our educational systems give greater attention to these social and moral questions in the programmes of our schools and colleges. These institutions should, as quickly as possible, be adapted to meet society's present urgent, social, and moral needs.

For, consider for a moment what will happen in these joint industrial councils, if each side comes to the discussion without such sound and sane knowledge of economic questions and such ethical views as will create in the minds of both parties common standards of social justice and right. On any issue of importance the work of the representatives will end in either of two very undesirable results. Either the deadlock between the trade unions on the one side and the employers' associations on the other will have been transferred to a debating organization in which neither side can bring conviction to the other; or, even if the discussions that occur in the industrial councils do bring about a satisfactory compromise, such decision will be refused

acceptance by the rank and file. Until both parties to the disputes are educated in economic matters up to the degree at which they can grasp clearly what is economically possible and what is socially best, and until they have clear ethical views as to the real end and purpose of all industry as social service, in other words, until they are so educated, either in early life or later, that they have the mental attitude and training practically acquired which will enable them to grip clearly and rationally these complex social, economic, and ethical questions when fully discussed with them, of what use can the mere creation of this new democratic machinery be ?

With labour sharing thus in the control of industry, one of the problems that will ultimately, but inevitably, come to the front for discussion and settlement will be the principles on which must be based the equitable distribution of wealth—a fair sharing of the joint product of industry among labour, capital, management and the community. The growth of human intelligence is making possible the production of very greatly increased wealth, that is goods and services of all kinds necessary to supply the needs and desires of human beings. Surely the further growth of intelligence, if accompanied by a corresponding growth in moral feeling and purpose, will gradually solve the problem of preventing the partial frustration of the great purpose for which wealth is created, viz., human well-being, the highest degree of which can be brought about only by its fair and just distribution. But this is an economic and ethical question of the greatest complexity and it lies at the very core of many other economic questions, for all of which a just and practical solution must be found. Nor is it just that the solution of this difficult but important question should be left mainly in the hands of two or even three of the four interested parties. A thorough study and discussion of it by all four interested parties is the only just method. No other method would be thought of under any other than the semi-autocratic conditions prevailing in industry. We are safe in saying that very few, if any, to-day have given sufficient study and thought to this question, though of such basic importance, to state clearly

the principles in accordance with which details of a just and right solution may be worked out in any given case. If I mention this question, it is not done with any intention of suggesting that I have reached clearly defined views on this vitally important matter, or of causing needless agitation by raising one of the most burning of economic questions, but rather that we may count the full cost of democratizing industry before deciding deliberately to adopt the principle. As stated, once the initial step is taken, I believe the only logical advance will lead inevitably to this problem. If, as seems inevitable, industry is to be democratized, whether agreeable to all or not, and if this is to be effected in the highest interest of all, then all sections of society should somehow, and as quickly as possible, be trained to think economically, socially, and ethically, so that at least a large majority will be in a position to appreciate the justice of the best solution of this and other difficult economic problems connected with industry.

The economic and ethical mental equipment for this can, I believe, best be formed by a rational educational system—a system that regards as its central aim the efficient preparation of on-coming citizens for citizenship in a commonwealth that aims to be democratic through and through, in industry as well as in matters of civil and political government. This is, in my judgment, the surest, if not the only, method by which society can avoid the economic confusion and distress, if not revolution, towards which we appear to be heading. I fear these distressing conditions may come about, if we do not clearly and frankly recognize the tendency of the present almost universal social movement and make adequate preparation, by widespread social and ethical enlightenment, to guide and to assist it. Our general educational systems should be so adapted as to prepare those who will to-morrow provide the capital and perform the mental and physical labour connected with industry, for a steady growth in an intelligent application of the democratic principle to industry. Industrial peace will never be attained as long as capital and management assume the right to a final say on matters intimately affecting the welfare and even the self-

respecting existence of a very numerous class, whose loyal co-operation is as essential to the success of every industrial enterprise as their own.

Is it clearly recognized that we are at the beginning of a great transition period in industry? Do we realize that the autocracy of capital is coming to an end? Such periods of widespread, rapid, social change are times of peculiar danger. It is in the power of the present members of society either to recognize the principle at work and to lend intelligent assistance to the movement, or to increase the social danger by opposing it.

There is, unfortunately, here and there, a revolutionary element in labour, usually arising from a vague sense of injustice which urges the mind toward aspirations, frequently impossible of attainment. Unless there exists a fair knowledge of economic facts and principles, making clear to all parties what is attainable and by what methods, and unless there exists also, in the great majority, moral purpose and determination, revolutionary schemes may have every appearance of being not only practical but legitimate and just. There is also, even among persons of fair general education who have paid but little attention to social and economic questions, too prevalent a belief that society can easily be reconstructed along the lines of some simple, socialistic formula; a belief, in other words' that a new social world can quickly be built by constitutional means. This state of mind, if widespread, is a very real danger. It may become the precursor of Bolshevism and red revolution. The greatest safeguard, if not the only effective safeguard, against it is widespread social, economic, and ethical education.

He who hopes to confine the waters of a perennial stream courts disaster. The springs of social energy and change are inexhaustible. The wisest course is to recognize social aspirations and tendencies, to aim to give them intelligent direction by universal and thoroughly democratic education and to afford them an adequate means of rational development and expression by efficient, democratic organization. This holds true in every field of social activity, inclusive of industry. It is the method that will secure the most real and rapid progress.

The democratization of industry is not more a matter of expediency than a moral necessity. The moral failure of the autocratic method in industry is shown by the hopeless divergence of view of capital and labour generally. The nation that leaped to its feet as champion of the great cause of world freedom, as soon as conscience so decreed, even though every historical tradition might be violated by the decision, will, I feel confident, never permit questions of business tradition or of economic selfishness to prevent her from championing the cause of democracy in industry, when once she is convinced of its justice, its righteousness, and its practicability. Its practicability rests mainly on an intelligent adaptation of the general education of all citizens to this end. The progress of democracy is indeed almost entirely an educational problem.

Industry sustains the life of every civilized human being. It lies thus at the very foundation of every other human activity. We degrade industry when we regard it solely or mainly as a means of private gain. Participation in industy is social service of the very highest order, since no other srcial service is possible without it. When this view is widelyoand clearly grasped and when it becomes an actuating motive to industrial activity, industry will attain to the position of real dignity proper to it—the dignity that is now generally conceded only to the pursuit of pure science. It will never be possible to engender a spirit of loyal co-operation between capital and labour in industry with nothing nobler to inspire it than the low motive of private gain. A widespread unity of spirit cannot be fostered without a great and worthy ideal. If we hope to reunite society by bonds of common selfish interests, we are doomed to disappointment. Only mutual service unites. Selfishness disintegrates. The honour that is supposed to hold together a band of thieves is mutual service while it lasts, but seldom withstands for long the disintegrating selfishness of their deeper nature. The inspiring unity begotten by a noble and worthy ideal was never more convincingly shown than by the alacrity of the response of every class in America to the call for defense of world freedom. No threatened suffering,

loss, or danger was a sufficient deterrent to hold men back in the presence of this great and noble ideal. Suitable organization for effecting perfect co-operation quickly resulted. But an attempted organization without the great central, unselfish purpose, would have effected nothing. It is primarily not a question of form but of spirit.

This ideal, that industry is social service of the most fundamental nature and therefore of the highest order, by no means precludes the incentive of intelligent self-interest. Neither did the ideal of world freedom. If closely regarded, both will be seen rather to include than to exclude the highest self-interest. The moral universe is fortunately so constituted that the highest self-interest is always best served, not by mere selfishness, but by considering the welfare of our fellow men. "He that saveth his life shall lose it." Selfishness is self-defeating. Unselfishness is the only efficient selfishness. The highest attainable industrial efficiency, which we are all striving after, must ultimately rest on this moral foundation of social service. This will be its ideal, and its method will be democracy and a 'square deal.' The nation that successfully and widely inculcates this ideal will lay a sure foundation of high individual as well as national efficiency and prosperity. The intelligent rooting in the minds of the on-coming generation of this higher economic ideal of industry as social service and the up-building of the less selfish character necessary to bring it increasingly into practical effect, afford the greatest educational opportunity to-day.

In an address before the college and high school department of the Ontario Educational Association last April, in a slightly different connection, I expressed this view in these words:

"Society already has before it a mass of unsolved social problems, some of which we have broadly outlined, and of which none exists of more fundamental importance to the welfare of all than the antagonism between capital and labour. This problem can, I believe, be solved only by applying the democratic principle to industrial relations. The Anglo-Saxon strug-

gle for democratic freedom has continued for more than seven centuries. It will not finally be won until the autocracy of capital is unrooted in industry. But the economic understanding, the ethical feeling and determination, the mental attitude—the indispensable psychological condition for getting together and viewing industry as a joint undertaking—must exist on the side of both capital and labour, before democratic organization for working amicably together can accomplish any good results. The idea must precede the expression; so must the psychological condition precede the organization. Hence we must aim to instil the truly democratic spirit of intelligent co-operation and social service in all, through our educational institutions, which citizens must rely upon to guide and quicken our social evolution in the manner outlined."

If we attach so much importance to the formation in the minds of all on-coming citizens of sound economic and ethical ideas and ideals, by every educational means at our disposal, why, it may be asked, do we further attach so much importance to the democratic form of organization as a means of solving the deadlock between capital and labour? Long experience, which has indeed culminated in the recent world calamity, has shown that autocratic rule in any sphere of life gives birth to ill-will, want of confidence, jealousy, and selfish ambitions. The secrecy of its methods creates the stifling and murky atmosphere in which spring up, as in a hot-bed, injustice, deception, suspicion, and distrust. This does not deny that the autocratic form of rule has, in both the industrial and the political fields, produced many results that, in outward appearance at least, were praiseworthy. But autocractic rule cannot safely be estimated at its face value. It has proven to be rotten at the heart. Superficially regarded, it may have appeared brilliantly successful, but it has proven itself a whited sepulchre. It talked peace but secretly plotted war. It preached 'kultur,' but attempted by sudden onslaught to wreck civilization and nearly succeeded in its fell purpose. Its much vaunted efficiency was only apparent. It was purely material. It failed at the very core. It failed to develop human personality and character.

The world today stands aghast at the full revelation of its human, or rather, inhuman product. Can we honestly deny that this indictment of political autocracy applies in some degree to the autocratic form of organization in industry? Does it not appear to be working similar havoc? Distrust, suspicion, and antagonism are widespread. The democratic form of organization gives the best assurance of any method which human society has so far discovered of the kind of open-and-above-board treatment and the 'square deal' on which alone confidence and goodwill can rest. Thorough organization must exist in either case. The difference lies in the origin of the authority and in the consequent responsibility.

A question that deeply concerns us as engineers, managers, or superintendents of industrial enterprises is that of efficiency. In this matter we have, I fear, much blame to accept for narrowness of view. Because of our special training in the material sciences and their application to industry, we have confined our attention altogether too exclusively to machines, to processes, to arrangement of plants, and to the external forms of organization. We have paid far too little attention to the 'imponderables'—to ethical standards, to psychological conditions and to the mental attitude of those on whom real efficiency must finally depend. Surely it must be apparent to every one that there cannot be any approach to the highest attainable efficiency in production, if there exists a general atmosphere of suspicion, distrust, and antagonism. Opposing forces tend to cancel one another. A high resultant can be obtained only by paralleling both the mental and the physical forces at work. Complete and efficient co-operation of the various factors in industry can be obtained only in an atmosphere of confidence and good-will. Efficient means of open discussion, knowledge of sound economic and ethical principles, and sterling character are essential pre-requisites of confidence and good-will, hence also of high efficiency.

Industry has so far been under highly centralized rule. In this government, capital and managemen have had predominating sway. Labour has had little or no share. We are, I believe,

at the threshold of self-government, or the application of the democratic principle to industry. We all need economic and ethical preparation for the more complex responsibilities this will cause to rest on us. Many old ideas and ideals regarding industry and business in general will find their way to the scrap heap. In the change, not only industry, but we ourselves will rise to a new dignity. Industry will become more worthy of the best efforts of all. It will in a new sense become the servant of the community and the handmaid of human well-being, in place of being largely a source of private gain and a cause of friction and conflict between opposing classes of society. It will thus come not only efficiently to supply the physical needs, but also to minister to the high moral and spiritual purposes of human life. In this new government, all interested parties, not omitting labour, the largest party, will have a voice. On this continent the entire machinery of industrial self-government has yet to be worked out, but it will probably be, as in England, of such a nature as to embrace existing, even though at present antagonistic, organizations. This safe method of building brick by brick on the foundation of existing institutions and experience is characteristic of the Anglo-Saxon genius for at once securing progress and avoiding revolution. In our study of this problem during the next few years, it will well repay us to give careful attention to the working out of the Whitley Scheme in Great Britain.

English-speaking peoples have been foremost in the development of democratic political government, which they have recently joined hands in defending. They are, let us hope, destined now to lead the world in applying the same principle to industry. This, if carried out on a basis of high economic and ethical ideals, as indeed it must be if it is successfully to be carried out at all, will make future war impossible. With the overthrow of Prussian despotism, the fight for freedom is only half over. Political and industrial autocracy may exist peacefully side by side; but political democracy and industrial autocracy, never. We may still have a long and difficult task ahead, but the job begun in Europe must be completed at home. The

seeds of social and international conflict are inherent in the present system of industrial organization, which rests on the self-disintegrating foundation of human selfishness, in place of on the solid rock of social service and human welfare. The awful suffering and carnage in Europe will not have been in vain, if, after it all and in some measure as a result of it, human society has successfully started reconstruction on this new industrial foundation which, if intelligently and diligently built upon, will gradually bring conditions of permanent, social, and international peace. In the Great War, the soldiers of America, Great Britain, and their allies have shown the most indomitable courage. Have we now the moral courage to look squarely at, and deeply into, this industrial problem and, if convinced of the soundness and justice of this method of working out the solution of it, to continue at home the courageous stand for democracy which our brave fellows have so valiantly taken in Europe?

It is the Nemesis of autocratic rule that the greater has been its apparent success, the greater and the more certain is its ultimate downfall. If the world war has impressed on us any one lesson more clearly than another, it is this: that no human social structure, however imposing in appearance or however brilliant in apparent success, can be permanent, unless it is founded on the eternal principles of justice and right. If the principles herein discussed measure up to this standard, then, if we are really seeking a permanent, rather than a makeshift, solution of the great industrial problem, we must seek to apply them. Industry will not in any case become fully democratized to-day, or to-morrow, or even in the near future. But, if we do not mis-read the meaning of present social movements of world-wide extent, progress in this direction is as irresistible as the tides. To prolong opposition to it is to risk being overwhelmed by the flood. The wise and sensible course is for society to recognize its own movement, to undertake the most careful study of the economic and ethical conditions giving rise to it, and to arrange as quickly as may be for widespread social training of its members, in preparation for such utilization of these new powers as may result in the greatest justice and benefit to all.

One of the most encouraging signs of the times is the steadily increasing amount of time in our technical societies and of space in our technical and other more serious journals, given to a discussion of the economic, social, and ethical aspects of industry. Let these discussions increase in both volume and earnestness and let this good work be backed as quickly and as strongly as possible by training the uprising generation under our general educational systems, from common school to university, modified and adapted to meet the social exigencies of the times.

INDUSTRIAL CO-OPERATION

By W. R. Ingalls

(Annual Meeting, Montreal, March, 1919)

A few weeks ago, in delivering an address before the Mining and Metallurgical Society of America, I took as my theme the "Economic Duties of the Engineer." Some people have done me the honour to signify approval of the ideas that I advanced in that address, and have asked me to elaborate some of them. It is a great pleasure to me to do this in a paper for the Canadian Mining Institute.

In the address to which I have referred I expressed the fundamental idea that the civilized world has experienced such great losses of capital and man-power through the war that it is confronted by grave prospects unless the losses be offset by great increase in efficiency in production, which will likely require an industrial reorganization. We, and especially we engineers, must strive for that and we may achieve it, but as an ominous counter-agent I see the spread of Bolshevism and many economic fallacies. I urged it, therefore, as one of the essential duties of the engineer that he saturate himself with sound economic doctrine and prepare himself to spread the gospel. I pointed out that labour, as the residual claimant upon the produce of industry, already gets about 80 per cent of the whole, leaving to capital only what comes to about 4 per cent on the total investment, and that if labour should attempt to seize that moderate share and should succeed in doing so, it would meet with the disappointment of the child who grasps a soap-bubble; that the grievances of labour refer in the main to inequalities in distribution among its own classes; and finally, that the only way of maintaining or improving the welfare of labour is to enable it to produce more. In order to enable it to do so, we must contemplate industrial reorganization and must accustom ourselves to think in terms of industries as a whole. That is what I have in mind in preparing this paper on "Industrial Co-operation."

What I am going to say will be, perhaps, different from what you expect. I am not going to tell you that we must pre-

pare for a new social order, or that the day of industrial democracy has come, or that henceforth the workers—meaning those who labour mainly with their hands—are going to run things. There has been a lot of talk of that sort, which has been sentimental, fallacious, and mischievous. On the contrary, I shall tell you that economic law is going to prevail and determine what people will do, and the less attempted interference with it there is, the better will everything be. I am going to tell you that labour, instead of holding the gains that it made during the war, is in danger of falling below the scale of living before the war. When I say labour, substitute people, for in the main the labourers are the people. We do not want to see any such downfall. It can be averted only by industrial co-operation. As I proceed, you will see that what I mean by industrial co-operation is nothing like what some people mean by industrial democracy. There is great unrest among workers all over the world. This is mainly economic, and is based on ideas ranging from the moderate thought that labour does not get its fair share of the produce of industry to the extreme thought that it ought to recover what it thinks has been stolen from it in the past. Before entering upon constructive considerations, let us pause to examine if there be anything essentially wrong in the arrangements the industrial world has already worked out for itself, not merely in one country, but in all civilized countries, for the system is everywhere about the same.

In my previous paper I argued that there is nothing essentially wrong, for the reason that labour is the residual claimant upon the produce of industry, taking all that remains after the deductions of the shares of the landlord, the capitalist, the entrepreneur, and the State; that even if those deductions were not made labour would not get any more; that such inequalities in distribution that exist are not between capital and labour, but are among classes of labour itself. The expression that labour is the residual claimant upon the produce of industry is one of the things that I have been asked to explain. It is in no way a new thought, but rather is it classic economic doctrine, advanced by Jevons and developed by General Walker. I can

offer no explanation so good as to quote freely from General Walker, without, however, using his exact words or confining myself simply to his statements.

On the lowest grades of land there is no rent. The cost of producing from them so much as must be produced to supply the needs of the people determines the price of agricultural produce. The rent of better lands is the excess of their produce after the cost of cultivating the no-rent lands has been paid. This rent does not affect the price of agricultural produce and does not come out of the remuneration of the agricultural labourer. The labourer can not get it, or any part of it, by any economic means. It must go to the landlord unless it be confiscated by the State, or ravished away by violence, and in either of those events it will soon cease and no longer accrue for anybody.

The remuneration for the use of capital must be high enough to induce those who have produced wealth to save it, instead of consuming it. Manifestly what is paid as interest for the use of capital is no loss to labour, for it makes more produce out of which labour benefits. Indeed, the higher the rate of interest the more is the benefit of labour. The worst thing that could happen to labour would be such a curtailment of the rate of interest, either from economic or arbitrary causes, as would diminish the incentive of people to save and induce them rather to gratify personal appetites and tastes as consumers.

Profits economically partake of the nature of rents. Just as there is a class of no-rent lands so is there a class of no-profit employers, the need for whose produce determines the market-price. From the point of no-profit production, profits range upward through the degrees of moderate profits, liberal profits, grand profits, monumental profits, but these consist wholly of wealth created by the entrepreneurs themselves, and no economic means would carry any portion of them permanently to wages. To be sure, they may be taken by the State as taxes, and by the State paid out in extravagant wages, but this destroys the economic balance and produces conditions whereof the result is that nobody makes any profit, industry languishes, and labour suffers. We are now witnessing just such a condition.

The matter of profits is one of the most complicated of economic questions, or perhaps I should say, one that is a subject of much popular misconception. Capitalists themselves are responsible for much of this through the common desire to make a good showing, and disinclination ever to allow sufficient for the depreciation and obsolescence of plant. In the metallurgical industry we see repeatedly how plants have to be discarded and rebuilt entirely; how others have to be abandoned owing to failure of the mining districts that once supported them; how industries become over-built in order to supply temporary needs with the eventuality of surplus capacity that has to be thrown away. Thus the American zinc industry in 1915-17 realized fabulous profits on paper, but a large part of them was reinvested in plant that subsequently ceased to have any earning capacity. Sometimes special conditions preclude a venture unless an extraordinary apparent profit can be expected. Thus, I once arranged for the purchase of a zinc smeltery on the basis of an annual profit of 50 per cent, for I could not estimate the endurance of natural gas supply for but little more than two years. The purchasers merely got their money back plus an annual interest that really did not justify their risk. The exaggeration of profits contributes to the dissatisfaction of labourers, who reason that their wages are pitifully small while the earnings of their employers are extravagant, and fail to appreciate that much of those earnings is merely replacement of principal or reward of extraordinary risks, without the prospect of which industrial progress would be checked. But after all, this is going into details and losing sight of the economic situation in its entirety, which is a common fault and source of misconception.

Rents, interest, profits and taxes being deducted from the produce of industry, all the rest goes to the labourers. "So far as, by their energy in work, their economy in the use of materials, or their care in dealing with the finished product, the value of that product is increased," says General Walker, "that increase goes to them by purely natural laws, provided only competition be full and free. Every invention in mechanics, every discovery in the chemical art, inures directly and immediately to their

benefit, except so far as a limited monopoly may be created by law for the encouragement of invention and discovery."

General Walker illustrated this by supposing a community to be engaged in a certain production, which is divided among rent, interest, profits, and wages. Let it be supposed that overnight a higher class of population be substituted, and that it produces five per cent more of goods. To whom does the gain go? Not to the landlord, for the material used makes no larger draft upon the land than formerly, and hence calls no lower grade of land into cultivation. Not to the capital class, for no more tools are required than formerly. Not to the employing class, for the substitution of intelligent workmen for those of a poorer quality has no tendency to drive production down to a less efficient grade of entrepreneurs. On the contrary, the effect would be to raise the line of no-profit employers from which the profits of successful employers are measured upward. Hence the gain must go to labour, for it cannot go to anyone else, and this, says General Walker, is what is meant by the labouring class being the residual claimant upon the product of industry, which upon the assumption of perfect competition is both profoundly true and of illimitable importance in economics.

This is an expression of a great economic truth in the abstract, but it may be put in a definite statistical way. We know it to be the truth not only from scientific deduction, but also from examination of the income of nations and the distribution thereof. Numerous studies of the income of both Great Britain and the United States show that of the whole produce 60 to 80 per cent goes to labour and that the remainder is but a relatively small return on the capital used.[1] But we

[1]In my January address I indicated labour's share of the produce of industry of the United States as having been approximately 80 per cent in 1916. Since then I have seen Dr. Bowley's excellent paper on the division of income in Great Britain, in which he arrives at the conclusion that labour's share in that country in some years immediately preceding the war was slightly more than 60 per cent. There is some reason to suppose that labour's residual share in the United States is larger than it is in Great Britain. However, I am giving these figures only as rough indications. In a subsequent paper I hope to offer the results of a careful and detailed study of this subject.

are able to show and to say a good deal more than that, to wit, that during the last hundred years of great industrial development the major part of the benefit has accrued to labour.

It was the theory of Karl Marx, from whose teachings are derived so many of the fallacies of the present time, that labour, in its narrowest sense, produces everything, and therefore that labour should have all that it produces. That idea is frequently expressed now, all over the world. We have already seen that labour gets almost all as it is, and what remains it would not get; for if profits, for example, are the reward of intelligence, the removal of intelligence would remove profits also. So long as the world was dependent upon mere man-power there was no very great advance in the wealth of nations beyond what was due to increase in population. There is no good reason to believe that an Englishman in the reign of George IV could carry any more weight per hour or for any more hours, or could exhibit any other superiority of physical power, than an Englishman in the time of William the Conqueror. The great increase in production has happened during the last century and a quarter and has not been because men have grown any stronger; but because mind has taught labour how to become more effective and has provided it with machines and with organization. It is the minds of the captains that have produced the great increase in wealth, and to those captains might reasonably have accrued all that they earned, but the economic principle that labour is the residual claimant prevented any such result, even if it were desired. The income of England in 1801 was about £180,000,000. The income of the United Kingdom at the same rate, but allowing for the increase in population, in 1907, would have been about £900,000,000. Actually it was about £1,950,000,000, excluding the revenue from foreign investments. In the words of Mallock, "the mind of the larger employers was the primary producer of an income of some £1,050,600,000 added to an income that would otherwise have been £900,000,000 only." Then he shows conclusively that of this increment the representatives of Mind got only about £250,000,000 for themselves, including both profits and the interest on industrial capital.

I have shown, I hope, that there cannot be anything essentially wrong in the existing system of the distribution of the produce of industry as between labour and capital. Labour cannot divide among itself any more than there is to divide, i.e., the total of what is produced. That is self-evident. It may attempt to seize the modest share of capital, but if it succeeds in doing so, that share dries up. If it confiscates capital itself it does not gain anything, for capital, without the directing minds to use it productively, ceases to be of advantage to anybody. The experiences in Mexico and Russia have shown what happens. The Bolshevists of other countries will lead to the same end if they have their way. Why is it that while socialists are shouting from soap-boxes, inflaming the populace with irritant poisons, while doctrinaires who hold professorial chairs are issuing fallacies, while a motley crowd in Russia is performing the most cruel and disastrous experiment ever known, we cannot drive into the heads of people that even as things are under the capitalistic system they get all they can, that they can get no more than they produce, and that it is not the power of the mass, but rather the minds of the few that have uplifted them to the stage of comfort that they enjoy to-day, which is vastly superior to what it was a century ago. If the Marxian doctrine had been true, labour would be paid now what it was 100 years ago—no more.

It is of profound importance to make the millions of workers see things correctly, for they are blindly approaching a time when adverse economic conditions are going to drive them, and no socialistic ranting or paternalistic policies by the governments are going to help them. The world has become so much poorer by the squandering of wealth and man-power during the war that no advance in the scale of living is to be expected from it. The prospect is just the reverse. The farmer does not lose his cattle and install improvements in his house because of his loss. The people of a city do not become profligate buyers of automobiles after a conflagration has swept away their houses. No more do nations become prosperous because war has consumed their substance. Instead of labour holding what it has gained during the war, it is probable that it will

suffer a relapse to a condition inferior to what it held just before the war, although the unions will struggle bravely against it. Fortunately we shall not see a loss of economic improvements, such as safety measures in industry and the provision of proper working quarters and conditions, because they are economic; but labour is in danger of losing the eight-hour day for the simple reason that it will have to work nine to ten hours in order to produce enough on which to live.

The inevitable will be violently but impotently resisted by the workers, who will not understand the compelling forces, and therein is something very pitiful, for the workers could do so much to help themselves if they would. "When men take twice as long as they ought in building their own houses," said Sir Charles Allom recently, "they increase their rents and thereby increase their cost of living before they increase their wages." He estimated that the workmen in the United States waste time to the value of over $8,000,000,000 per annum, an estimate that is only rough and requires a good deal of explanation, but nevertheless conveys an idea of the magnitude of this economic loss. He adds correctly, however, that capital "is the mainspring of enterprise and advancement and labour's profit. Rich men are rich not because they have robbed the working man, but in spite of the working man having robbed himself." But, alas! we cannot make the working men see this and try to help themselves, and therefore we are obliged to try to make good the losses of the world, avert backsliding, and lay the foundations for further progress without their aid and even in spite of them. And thus, after this long preface, I come to my thesis of industrial co-operation as one of the means of economic improvement that at this juncture is essential.

Now, economic improvement may be defined as the avoidance of waste. I can think of no better definition. I do not mean merely the elimination of obvious wastes, such as were features of many gospels that were usefully preached during the war, but rather the major things that we do not yet regard as wastes, or if so, do not yet know how to eliminate them. The diversion of unnecessary men, the prevention of misdirected

effort, the increase in the foot-pounds of the man-day of work are all forms of cutting out the waste. If the railways of the United States could, by virtue of improvements in organization, invention of automatic devices, etc., be operated with only one million men instead of two million, there would manifestly be an enormous saving of labour, which could be diverted to the production of something else. The avoidance of waste is therefore fundamentally the avoidance of the waste of labour.

I must now pause to refer to another economic obstacle. I have already described the discouraging impediment that exists in the fallacies of the workmen. We have also to contend with something quite similar and equally serious in the minds of a large part of the employing class. This is the idea among thousands of them that they too do not get their due, that something is somehow stolen from them—in short, that they can get more than they produce. This idea finds expression in agrarian movements among the farmers to contest what they deem to be robbery by the millers and railways. It finds expression in the never-ending grievance of miners against the smelters. During the war the attitude of these people assumed the form of a rapacity that was only a little less extortionate than that of some classes of labour, and which has a very ugly and dangerous aspect now. During the war governments could take billions of dollars from some classes of people and scatter it among others without thinking of anything but the immediate object of winning the war. There developed the pestilential idea of price-fixing, which it is going to take a long time to eradicate. I do not intend to discuss that intricate subject, which would require much more time than is at my disposal now, but I am going to point out some of the mischievous things that are inspired. An example is this: In the United States we had very high prices for sheet zinc, due to deficiency in rolling capacity. The Government fixed a restrictive maximum, which was still high, and the market price stuck to that maximum owing to the shortage in supply. Ore producers in certain districts claimed a participation in the profits of the rollers, who were also smelters, and through the agency of the Government obtained a grant of an ore price far above the market price.

The ore of this grade being more than the smelter-rollers could take, the demand was allocated among themselves by the miners, who sold their surplus at the market price. Thus, instead of letting the rollers make monumental profits and recovering them through taxation, the profits were divided among numerous ore producers, who frittered them away.

But to finish this story. Although the production of zinc required no stimulation, there being on the contrary over-production, the miners deemed the time ripe to compel the smelters to pay them the prices they would like to have, and the Government bowed to them and arranged things. This killed the goose that laid the golden egg. The smelters assented to the scale and then did not buy any ore at all, drawing upon their stocks and diverting their buying to other districts that were eager to sell at the market price.

There was a great effort made to have the Government guarantee minimum prices for some ores. The legislation was not enacted until about a month before the armistice, and then not in the form desired by its promoters; but as a result of concerted action, there is now to be an indemnification of mining losses incurred, it is alleged, in anticipation of the legislation, although in fact the bottom had begun to drop out of the markets two months previously.

The cotton-growers were immune against any price-fixing, and had a very sporting and highly profitable time, but now that the price of cotton is declining in company with that of other commodities they are demanding a guaranteed minimum.

These instances illustrate one form of industrial co-operation, a form of co-operation in dipping into the treasury of the public, but it is not the kind that I mean, and it is a kind that will infallibly make everybody poorer, the co-operators included. On the contrary, one of the first essentials now is for every country to rid itself of its useless industries. If anybody is trying to raise bananas in Canada (I suppose it might be done under glass) he is not adding anything to the wealth of the country. He is subtracting from it. Instead of encouraging him, he ought to be suppressed as a national waster. However,

I will give a less extravagant example of my meaning. We have in the United States a considerable quicksilver industry, but owing to the poverty of our ores the metal is costly to produce. We can buy quicksilver much more cheaply from Spain, where there are rich ores. Our domestic industry can be kept alive only by a high protective tariff. That would be a very costly tax upon all the people, a national loss of money, in order to afford a precarious existence to a few people who would be better doing something else. I shall immediately hear the suggestion of the necessity of military preparedness. Very good. Quicksilver is a highly essential article, and last year our munitions requirements took a large part of the domestic output, but a little figuring will show that it would be far cheaper for our Government to buy from abroad the supply for several years, and pay storage and interest charges than to keep our own mines going.

There are not a few industries of this class in the United States, and in Canada you have them, too. I am not depreciating the principle of a protective tariff, or even of a bounty, in all cases. A country may have national resources, or opportunities, for the development of which a temporary stimulus may be helpful. In such a way was the manufacture of tin-plate in the United States established as a great industry. But the maintenance of production out of poor, hopeless ore deposits by means of donations at the expense of all the people is an economic crime. I repeat, therefore, that one of the first things in the way of industrial co-operation that should be done is the elimination of useless industries. I think that it is a great function of professional organizations like this to study and determine what are useless industries. Governments, subject as they are to political influences, cannot in time of peace, whatever they have done in time of war, form so impartial an opinion. Indeed, the suppression of non-essential industries by the war boards was generally of useful industries for the sake of those that under peaceful conditions would be useless.

Probably there are rather few absolutely useless industries. If the number of them was large a country would soon become

bankrupt. Most industries are useful and profitable to a more or less degree, and, assuming that national resources afford the proper foundation, their economic position is probably in proportion to the co-operation that exists in them. I shall confine my illustrations to the metal industries, feeling a certain confidence that whatever lessons may be deduced from them and whatever opportunities for improvement in them may be discerned, may be extended to almost all other industries.

It seems to me that of all our great metal industries copper is the best organized industrially and affords the best example of industrial co-operation, which is the more remarkable in that there is no formal association, nor indeed is there any need for one. The satisfactory situation in this industry has resulted from the transparency that has been produced in it. By transparency I mean the excellent knowledge about all its affairs that is possessed by everybody, resulting from the withdrawal of all veils so that everybody can see through everything. The production is in the hands of a relatively small number of companies, and even the smaller of them are relatively large concerns. The controlling interests are fewer than the producing companies, but not so few that there is not sharp competition among them in the market. There is a perfect exchange of technical information, both through the medium of the technical press, the transactions of the societies, and inter-works visits. If at one works some new improvement is developed, such as coal-dust firing, no effort is made to keep it a secret, but rather is there an *esprit de corps* which leads to the prompt spreading of the details and the adoption of the new method wherever advisable. There is a similar publicity as to the methods of accounting, operating costs, and financial positions. The industry has learned the value of prompt statistical information, and now co-operates as a matter of course in furnishing the data for it. Producing a metal that is generally in demand and for which there is no substitute, with conditions that have forced producers to resort to poorer and poorer deposits and to devise improved means permitting their profitable exploitation, the copper industry has escaped the burden of over-capitalization. The industrial co-operation in the copper industry,

developed naturally as it has and both tempered and stimulated by commercial competition as it is and should be, is so excellent that I am unable to suggest anything that should be done to improve it, except even better statistical information.

Among American mining and metallurgical industries I am inclined to put iron and steel next to copper in industrial co-operation and therefore in general efficiency, but I am not so familiar with it, and therefore hesitate either to commend or to criticize. The metallurgy of iron and steel certainly does not figure in current technical literature to anything like the extent that does the metallurgy of copper, and data of cost of production and other things are far less easy to ascertain. The industry is well provided with statistics of production and some other rudimentary data. It is chronically over-built and subject to the alternate conditions of feast and famine. I feel convinced that there is much less transparency in this industry than in copper, and that the state of what is only translucency, or perhaps I should say semi-obscurity, is an obstacle that might advantageously be overcome by the right kind of industrial co-operation, and I say this although there is an industrial organization for just that purpose.

Passing to the lead and zinc industries, we find less satisfactory conditions. Both the smelting of galena and of miscellaneous silver-lead ores, which result in producing the pig-lead of commerce, have been brought to high degrees of perfection, to be sure, but the industry as a whole exhibits very little co-operation. Thus, until within the last few years, the mining companies of the southeastern Missouri district, one of the major sources of lead supply, had very little to do with each other, although the exchange of information respecting the ore deposits would have been of great value to all. In the marketing of pig-lead all of the producers were hostile and secretive. There were no statistics available except the annual figures as to production, and there was always mystery respecting unsold stocks. Amid this obscurity as to commercial conditions, the market was subject to sharp ups and downs, affording a lucrative hunting ground for speculators. In silver-lead smelting a

large part of the works had passed into the hands of one great company, whose relation with its clients—the sundry ore producers—were neither of the happiest nor conducive to the best interests of both parties. In British Columbia, where there is only one smelter, a similar condition of affairs has existed and still exists.

I do not intend to digress into any lengthy discussion of the chronic controversy between miners and smelters. The clearing-house among Colorado smelters, immediately preceding the general consolidation of American smelters about 20 years ago, was an excellent example of effective industrial co-operation. Previously no smelter could work to the best advantage; for, needing ferruginous ore, calcareous ore, siliceous ore, plumbiferous ore, and argentiferous ore in certain definite proportions, he might be short of one or two classes and consequently unable to compound the most economical smelting charge. The clearing-house became a reservoir and equalizer, which improved economic conditions to the advantage of everybody, miners as well as smelters. The consolidation perfected this idea, and in the course of time improved greatly its technical practice. While the company out of this derived large profits for itself, as it should have done, without any doubt the ore producers benefited even more. A large part of them would not be able to operate at all to-day were it not for the economics of the big company, whose margin per ton of ore treated is, on the average, no more than reasonable, and indeed I might say, modest. In my own study of the affairs of this company about 10 years ago I showed that its profit on all ore smelted was only about $2 per ton, while in some important districts it was only $1. Nevertheless, it is undeniable that on the part of the miners, not only in this industry but also in others, zinc for example, there survived undisguised feelings of suspicion and hostility toward the smelters, instead of which there should be frankness, friendship, and co-operation. Who will gainsay that if such a relationship could be inspired it would fail to be of great advantage in improving the efficiency of the industry as a whole? In the commercial end, the marketing of the product, and in general matters of administration and introspection, I

am sure that the leaders of the lead producing companies profited greatly from their association during the war. They learned something of what it means to think in terms of the industry, and not merely as individuals.

I can illustrate best what I mean by thinking in terms of an industry by referring to an address that I made to the zinc producers of the United States last July. The American zinc industry at that time was already in a dangerous state owing to the aftermath of the feverish stimulation in 1915 and 1916. The fabulous prices for spelter during that period had the natural effect of increasing producing capacity enormously, primarily owing to more production being needed irrespective of cost; but from the outset it could be safely prophesied that the day would come when there would be a surplus of capacity, and ecstasy would be followed by depression. I shall not spare the time to trace these interesting experiences in commercial economics. Suffice to say that the early part of 1918 saw the extinguishment of the ephemeral plants, while of the substantial concerns remaining, three-eighths of their capacity was idle at the mid-year, with fair prospects that it, representing a capital of $10,000,000, would be idle indefinitely. Besides this, the industry was threatened with serious alterations in economic conditions. At this juncture I advised the industry to co-operate in a propaganda to increase the use of zinc, with the aim of substituting it for dearer metals, and to take steps to increase efficiency in production and selling, among which would be a well-developed statistical service, and the organization of a good system of uniform accounting. The desirability of increasing the uses of this metal, from the standpoint of the producers of it, is of course self-evident. But with respect to increasing the efficiency in selling and producing, the expression of the means in general terms will perhaps fail to convey clearly the ideas, wherefore some elaboration may be welcome.

The foundation of successful marketing is knowledge of conditions, both as to consumption and production. If everybody could see those conditions at all times the markets would be comparatively stable, just as are those for aluminium and

nickel, which are controlled, on the producing side, by monopolies. Now, I do not intend to argue in support of the monopoly idea—my argument will be quite the reverse; but it is clear that the director of a monopoly, having full information respecting conditions of production and good information as to consumption, can eliminate minor fluctuations in price and needs conform only to broad swings of economic conditions. I do not think that monopoly, not even beneficent monopoly, is a good thing, but certainly it arrives at the result of relatively stable prices, and the nearer the same result can be attained under conditions of free competition the better it is for everybody except speculators. Manifestly the only means of accomplishing anything of that sort is knowledge, and, fundamentally, statistical knowledge. I think it can be shown that in industries which have acquired such knowledge the fluctuation in their markets have moderated, but in no case is the statistical service yet as good as it ought to be.

I need scarcely point out the incalculable benefit both to capital and labour if it were possible to determine the state of economic conditions more promptly and more accurately than is possible at present, enabling both producers and consumers to cut their cloth accordingly, and incidentally eliminating the speculator, who in our present organization is simply a person who is more gifted for seeing in the dark than are most. There would be less waste of capital in overbuilding means of production, there would be fewer periods of over-stocked markets, and the lot of the working man, assured of more regular employment, would be infinitely better. Of course, the last is just one of the things that socialists talk about effecting, and that is one of the expressions of a justifiable discontent, but the cure for it is not State control of industry, nor industrial democracy, but merely industrial co-operation in a sound and simple manner.

The improvement of efficiency in production is neither so simple nor so easy. I put this under the head of organization of a good system of uniform accounting, for until that is accomplished nobody can know just how the component parts of an industry stand, and what ought to be done to improve things

generally. No man can know whether his business is being conducted efficiently or not unless he knows not only his own costs, but also has some standard with which to compare them. By such comparison he may ascertain that his costs are too high, and then upon analysis he may find that he is employing a wasteful type of furnace which it would be economical to discard, even at the expense of a new one of greater first cost. By this time the services of the engineer have been called in, which services are never invoked soon enough or often enough, or extensively enough. In some districts where the mines are small it would be advantageous for their owners to co-operate in retaining the services of one or more engineers for general advice. A general industrial association should have experts to aid the district and local groups. Manifestly, there would be no reason, whatever, why a company sufficiently strong and enlightened to do its own engineering and its own research work should not continue to do so. However, that should not cause the big company to hold aloof from the general co-operation.

The strong must help the weak, and in most cases it is the weak who know the least about their own business. Moreover, I conceive that it is in the interest of the strong to help the weak, and certainly it is never to their loss. The Anaconda Copper Mining Co., which has been a leader in developing the practice in copper metallurgy, has been generous in communicating information to other producers, and so far as I know has not lost anything by its generosity; rather has it gained something for itself. I have an idea that no one concern in any business can be very prosperous unless its industry as a whole is fairly prosperous. Let us suppose, for example, that in Detroit, which has become a great centre for the manufacture of automobiles, there were one or two concerns, which by reason of excellence in design and construction of their cars, good business management, etc., stood head and shoulders above all the rest as commercial successes. The fact that Detroit had become such a centre inspired many kinds of accessory and elemental manufactures, even to the rolling of sheet copper and the production of pig iron. Suppose now that a general blight overtook automobile manufacturing, compelling many makers

to suspend operations and consequentially many of the industries that supplied them with necessary things; but that the one or two conspicuous concerns escaped the blight. Certainly they would not escape the consequences, if the local rolling mills and manufacturers of rough parts ceased production and if the population of skilled labour dispersed. The connection between one concern and all of the rest in its industry may not always be so clear as this, but that there is a connection is sure, and it is a reason why the strong should help the weak.

Now, labour has a direct interest in this branch of industrial co-operation, just as it has in the statistical service. Earlier in this paper I have pointed out how labour's residual claim on the produce of industry is determined by the deduction of the landlord for rent determined by the no-rent lands and by the profit of the employer as determined by the no-profit class. Obviously, therefore, everything that increases the produce of agricultural lands and contracts the circle of no-rents lands, or that increases the produce of the mines and factories and reduces the ranks of the no-profit class of employers, is directly in the interest of labour. Although it would diminish the profits of some very successful employers at some times, they too would gain on the whole, for they would utilize their plants more fully and more steadily, and while making smaller profits per unit of production would make more in the aggregate. In brief, this is simply another expression of the gospel that it is to the interest of everybody to produce the most goods that can be produced. It is not money, or money-wages, that people want, although unfortunately that is what most of them erroneously think they want; but what they really want is the goods for which money can be exchanged.

If I should extend my remarks under the title of "Industrial Co-operation" which, of course, is broad enough, to include co-operation by labour itself, I should put that at the head of everything, but while the eradication of its unfortunate delusions is not hopeless they are undoubtedly so deep-seated that any conversion to sound thinking will necessarily be slow. The labourers must be shown, and of course they can be, that by

sound economic theory labour is the residual claimant upon produce of industry; that its residual claim in America is 70 to 80% of the whole; that statistics prove that it gets it; that they show that when mind increases the produce of mere manual labour the latter gets the major part of the increment; that of the part of the produce of industry that they do not get they cannot get by any economic means; that in trying to get it by confiscatory means they not only do not get it, but also lose more or less of what they were previously getting as their residual share; that the only way they can get any more than they do now is to produce more; that slacking in any form, either by working full time at only partial efficiency, or by working only part of the time of the week, is directly opposed to their own interest, and that they are greater sufferers thereby than anybody else. "The day when labour exerts its full energy," says Sir Charles Allom, "it will inherit the greatest dividend in the world," and he adds, "Never did labourers exhibit less judgment in disturbing employers than in their selection of this moment. If they are left workless it will be their just desert."

But to instil these truths, while the minds are filled with fallacies of Karl Marx, which are so gross that they have been dismissed by the intellectual socialists themselves, will be slow, and the crisis into which the world has entered will not await an educational movement among the masses. Therefore must we appeal to the directive factors in industry and urge upon them the exertion of new effort to produce more, and as a means toward that end I advocate industrial co-operation, and thinking in terms of industries as a whole. In the programme that I have outlined herein it will be perceived that the arrangement of cartels or commercial agreements other than what are based on sound economic grounds plays no part. Anything that is founded on the idea of restricting production or interfering with the free play of competition would be the antithesis of my thought. Nor does my programme comprise the co-operation of labour—not that it would be unwelcome, but rather that it is not foreseen that it can be won. The only co-operation by labour that would be worth anything is the common-sense

kind. The talk about industrial democracy is clap-trap and does a lot of harm. It is mischievous when one of our leading newspapers writes editorially like the following:

"Let us recognize the truth that the autocracy of capital is coming to an end. Nobody more clearly recognizes this than the autocratic capitalists themselves. At least, the more intelligent among them have their eyes wide open to what is going on. They have fully made up their minds that a larger share of the new wealth produced is to go to the men and women who contribute the labour that enters into its production. They have also made up their minds that heavier taxation of rich men has come to stay. More important than this, they have come to see that plans for developing industry are hollow which do not provide for the willing co-operation and interest of working men. No one is more eager to accept and apply sensible schemes of that sort than the fully wide-awake among the employing capitalists."

What is, or ever was, the "autocracy of capital?" It sounds bad, but it does not mean anything. Substitute the "authority of the directing minds" and we shall come nearer to the truth. Diminish that authority in any way and production also will diminish, and the men and women who labour will not be thankful. No larger share of the new wealth is to go to them unless they themselves make it larger by their own efforts, or what is more likely, unless it be made larger by new efforts of the directing minds whose authority it is sought to curtail. Heavier taxation of rich men may have come to stay, but that in itself is going to be to the detriment of the men and women who contribute the labour that enters into production.

If industrial democracy means merely the improvement of working conditions, and listening for advice about it from the men and women who work, by all means let us have it; but who has that simple conception of the meaning of the phrase? Employers ought to provide proper working places; they ought to make them safe and light and sanitary for the sound reason that thereby they will increase efficiency. For the same reason they ought to provide compensation for sickness and accidents,

old-age pensions, and in general should take care of their people. But the more enlightened employers already do this to a more or less degree, perhaps not enough, but nevertheless progress in this direction has been steady. All of this falls, however, under the head of industrial co-operation, which may be urged in every possible direction that is economically sound. The jargon 'industrial democracy' is simply an expression of the discredited theory of Karl Marx, repudiated by socialists themselves, who recognize, in the words of Mallock, that, "in any complex system of industry, such as that which prevails to-day, the efficiency of the workers as a whole is the average efficiencies of the many multiplied by the efficiencies of the few," the Few being "the natural monopolists of ability," whose function is to issue orders, while that of the Many is to execute them with strict obedience. I may well conclude this paper with Mallock's own concluding words in his great book on "The Limits of Pure Democracy," to wit: "In any great and civilized State, *Democracy only knows itself through the co-operation of oligarchy*, or that the many can prosper only through the participation in benefits which, in the way alike of material comfort, opportunity, culture and social freedom, would be possible for no one unless the many submitted themselves to the influence or authority of the super-capable few."

DISCUSSION.

MR. C. V. CORLESS (*communication to the Secretary*):—Many members of the Institute must have been painfully surprised by the supercilious reference (as it were in a haughty and contemptuous aside) to industrial democracy—an expression at which the author of the article on "Industrial Co-operation" flings the choice epithets, "clap-trap" and "jargon." It must surely be known to the distinguished and widely informed retiring editor of the *Engineering and Mining Journal*, that the question of industrial democracy, which he thus waves aside with a sneer, is one that is to-day receiving the earnest consideration of very many of the most thoughtful citizens of the English-speaking world. In Great Britain, it has been incor-

porated by the government as the central idea of the national policy of post-war, economic reconstruction; in Canada, it is a subject of present inquiry by a Royal Commission appointed by the Cabinet to investigate industrial relations; in the United States, which was fortunately less profoundly affected by the war, it is receiving the serious attention of many eminent citizens and the principle has already been adopted by a few large business organizations.

If the numerous discussions on this subject, which have appeared in the publications of the Institute and in other economic literature during the last two years of the war and since the armistice, have impressed the mind of the author of "Industrial Co-operation" as dealing with phrases which expressed no reality but were mere "clap-trap," "jargon" and meaningless stringing together of words, then it would appear to be a hopeless undertaking to attempt to convey to his mind the ideas which are intended to be expressed by such phrases as "industrial democracy" and the "autocracy of capital," toward which he appears to feel such violent antipathy. If he is better pleased with the substitute he suggests for "industrial democracy," viz., "authority of the directing minds," I feel quite sure that no one who cares more about the reality than the manner of expressing it will take exception to this choice. The whole point is the origin of this authority. If this authority originates solely or mainly in a board of directors, then here, as in political government, authority exercised without the consent or approval of the governed constitutes autocracy, however it may be disguised, and since the authority is conferred on the board of directors by the shareholders who elect them and who exercise this privilege because of their ownership of capital, it seems, for brevity, reasonably expressive to call such authority the "autocracy of capital." If, on the other hand, by means of joint councils with equal representation of the shareholders and the workers, or by means of other suitable organisation for the purpose, this authority is exercised with the consent and approval of the workers, this method, by contrast, seems to be reasonably expressed by the phrase "industrial democracy." But, as stated before, I have no desire to make an issue of the mere choice of phrase-

ology to be employed. Every well-informed person who has even a general knowledge of economic and social questions, knows that this idea not only did not originate with Karl Marx, but that it is contrary to his views. It may be that unfortunate associations cling to the expression, "industrial democracy," from use of an equivalent expression in the original of his teachings; but the idea underlying the expression traces its roots more truly back to Runnymede and beyond, even to the instinctive love of freedom which we are safe in believing is as old as human life, since it is characteristic of human life.

But the author confuses changing the origin of the authority with lessening the authority itself.

This is slight compliment to the intelligence of workmen. The author's opinion of course rests on a radical difference of view as to the effectiveness of self-discipline as compared with the discipline of external authority. The increasing failure of the latter method is shown by the growing unrest of workmen and the increasing frequency of strikes. A good example of the effectiveness of discipline by the men themselves, well-known to all who have experience, is that of any group of workmen who take a joint contract, say in shaft-sinking or in any other suitable kind of work in a mine. Here, selection of partners is carefully made and no clandestine shirking is permitted. Experience of this kind and knowledge of human nature in general are most convincing to those who believe not only in the justice but also in the effectiveness of industrial democracy that, if both the method and the spirit of joint control are introduced, the self-discipline of the workers will be more strict, thorough and efficient than the super-imposed authority exercised under the present system of industrial organization. Workmen who become definitely interested in, and identified with, an industry because the method of organisation is such as to convince them that their voice is a factor in its conduct and that their share of the product is just and right, will not have the spirit of opposition and reluctance continually aroused and will not stand for any shirking or 'horse-play' on the part of their fellow-workmen, which might lessen production by throwing out

of balance a whole series of operations. If, further, the organisation is such that their ideas for securing increased efficiency are readily available and suitably recognized, those who believe in industrial democracy hold the opinion, which they believe to be well founded, that the benefit both to industry and to the workmen personally, to say nothing of the saner ethics of the arrangement, will be very great.

Those favouring this view realise, quite as fully as does the author of the article, the surpassing necessity of increasing production to the utmost, in order to repair, in the shortest possible time, the immeasurable material havoc wrought by the war. But they believe that the greatest brake on the wheels of production in the industrial world to-day is the reluctance and antagonism of the workmen. This mental attitude arises from the suspicion that they are being exploited in the interest of capitalists, and from the accumulating ill-will due to an economic system that does not properly regard the rights of human personality and that leaves the workers a constant prey to the grinding uncertainty which arises from being to a great extent a helpless and voiceless unit in a vast organisation which they either do not understand or wholly misunderstand. This is why a practical grounding in the fundamental facts and principles of economics and ethics must become an essential part of any comprehensive scheme looking to a final solution of this greatest of present social problems. The groundwork of such education must be laid in the schools, but the superstructure will be built by the intelligent experience acquired, and the added responsibilities born, by the workers, arising from their new place and outlook in a democratically organized industry. This complete change no sane man would expect to bring about to-morrow or next year. But the change in organisation can be made more quickly and, if made, it will go far towards meeting present difficulties.

The frank discussion of the question of industrial democracy, the author of the article under discussion believes, "does a lot of harm." He severely censures, as "mischievous," a newspaper editorial paragraph which most right-thinking in-

dustrialists to-day would be prepared fully to endorse. But what shall we say of the harm and mischief of trying to suppress discussion of these most vital matters, which are uppermost in the minds of all thinking men, who are looking for a sane and righteous solution of our present social and industrial difficulties, and who have not been in a "Rip van Winkle" state of economic and social slumber during the period of the war. The movement and the discussion of it can no more be suppressed than can the feeble efforts of man succeed in confining the waters of the Mississippi or in damming the Gulf Stream. Certainly, no attentive reader of *The Engineering and Mining Journal* during the past five years can criticise the policy of that journal as having been inconsistent with the author's views in this regard.

The author, both in this paper and in his address to the Mining and Metallurgical Society of America appears to be deeply impressed by certain "economic laws" and treats of them as if these "laws," as well as deductions drawn from them, were as rigid and certain as the laws of mathematics or physics. This adds greatly to the apparent weight of the argument and tends to create the impression of finality in regard to the conclusions drawn. Deductions from economic laws based on unrestricted competition, as taught by Adam Smith and his followers, were long regarded in England as even more unavoidable and scientifically certain, but have recently been seriously brought in question. At present the *laissez faire* conduct of industry based on these deductions is admitted by most economists, as well as most of the thoughtful business men of Great Britain, to have been the chief cause of her well-known prewar economic and social difficulties which were so serious as, in the opinion of many, to threaten revolution. The remedy for these is now believed to lie in a reversal of many of the teachings of the "Wealth of Nations," some of which, unfortunately, were inconsistent with the laws of other humanistic sciences as, e.g., psychology and ethics. Even if we assume the truth of the so-called law that labour is the "residual claimant," which the author uses as an important starting point, of what practical use is it? General Walker, in the quotation from him given by

the author, specifically adds the conditions, "provided only competition be full and free." This is the very proviso which has been discredited and is being discarded in Great Britain, which was long ago discarded in Germany and which is discredited by the author himself, as shown in the paper under discussion, the very title of which, "Industrial Co-operation," indicates this. Then why does he weary the reader with page after page of discussion in a laborious attempt to prove, as a deduction from this so-called law, that the workmen's share of the product cannot be greater than it is? This surprising conclusion will be questioned by many, who know only too well the psychological and ethical laws which are wholly or partially ignored in the methods by which wages and profits are fixed. That there is a share of the product in any given industry beyond which the earnings of the workmen cannot go, without lessening the earnings of both labour and capital by injuring the industry, is so obvious as scarcely to need statement. But that the existing methods of determining the just and proper shares of labour and capital, which in many cases are based on higgling, force, or a kind of hide-and seek, cannot be improved upon, few will be ready to admit. In how many cases is the whole question openly, frankly and fully discussed with the most intelligent leaders of the workmen, so as to convince them that the division is really based on principle and is not the result of juggling with figures? Does any one know of any other method of finally solving the deadlock between capital and labour than the open-and-above-board method? It is NOT a question of our likes and dislikes; it IS a question of the correct interpretation of present social and industrial tendencies; it is very unwise for business men to refuse to look at this tendency and to treat this industrial movement with contempt. Industrial democracy has nothing to do with Socialism of the Marxian or any other type. Its purpose is merely to meet the legitimate aspirations of by far the largest number of our fellow men, in such a way as to ensure social and industrial progress by evolution rather than by revolution. Greater harm and mischief are likely to result from refusal to discuss this question than from full and open discussion of it and ad-

mission of the fundamental economic, psychological and ethical truths underlying it.

In any case, all recognize that the laws of any one science cannot be inconsistent with those of other sciences. All real laws of science join in a higher unity of truth. If any so-called "law" of economics proves to be inconsistent with established laws of ethics, psychology, sociology, jurisprudence, or any other of the humanistic sciences, we are justified, to say the least, in regarding it with suspicion. The "law" from which the author appears to deduce the conclusion that "whatever is, is right," or at least approximately so, in the matter of the present distribution of the product of industry, will, I am certain, not stand this test. It will fail to bring ethical conviction of its truth.

THE VALUE OF AN INVESTMENT WITH VARYING YIELDS.

By Alfred C. Lane.

(Annual Meeting, Montreal, March, 1919)

The present worth of a bond whose annual payments and maturity are known is simply obtained by adding the present worth of the annual and final payments. One uses a rate of compound interest in discounting these payments to obtain their present worth that the security of the bond and the rate that money yields justifies. If the bond is as sure as a savings deposit, then the present worth of a payment is the amount that, put in a savings bank now, will amount to the payment in question at the time it is due. This may not be the rate of interest named in the bond. For obtaining such worths there are many tables. For instance Lefax 5-127 is a graphic, and Lefax 3-167 and 3-168 printed tables.

There is, however, an allied and somewhat more difficult problem which I treated popularly in the *Magazine of Wall Street* (1916, p. 744), that has theoretic as well as practical interest.

Suppose we are considering an investment whose return is not fixed and regular like that of a bond. Let it be for instance an oil well or a copper deposit, an investment such as is represented by stock rather than bonds.

It is obviously grossly incorrect to value it—prospectuses sometimes invite you to—as though the total output at some estimated profit were so much cash in hand. A fairer way is to distribute the total production reasonably through a series of years, and estimate the present worth of each annual product separately.

Two methods of handling such problems may be clearly seen by taking up two special cases, the one involving a diminishing yield like that of an oil well, with the profit assumed constant,

the other assuming a constant yield but with the price of the product fluctuating with good and bad times.

1.—Continually diminishing yield.—Oil wells generally fall off in flow after the beginning and a total yield on the average of 1,800 times the yield of the first full day has been suggested as a plausible assumption for the yield. But just how long a life should be assumed is a debated question, and as a matter of fact it varies. If, however, we assume, as we should in estimating the value of the yield of an oil well years hence, a liberal rate of discount, it makes really little difference in the present worth whether we assume a definite limit to its life or not—there is a very definite limit to its value.

Suppose we assume such a curve of declining production as M. L. Requa has recently given (*Bulletin* A.I.M.E., Feb., 1918, p. 410). Requa uses an 8% discount rate, which is covered by Lefax table 5-127. If we want to use this or higher rates of annual discount and only have tables going up to 6% like Lefax 3-168, we can do so by using a 2% quarterly rate instead of 8% annual rate, and in assuming that 8% compound discount for 10 years is equivalent to a 2% discount for 40 years, we

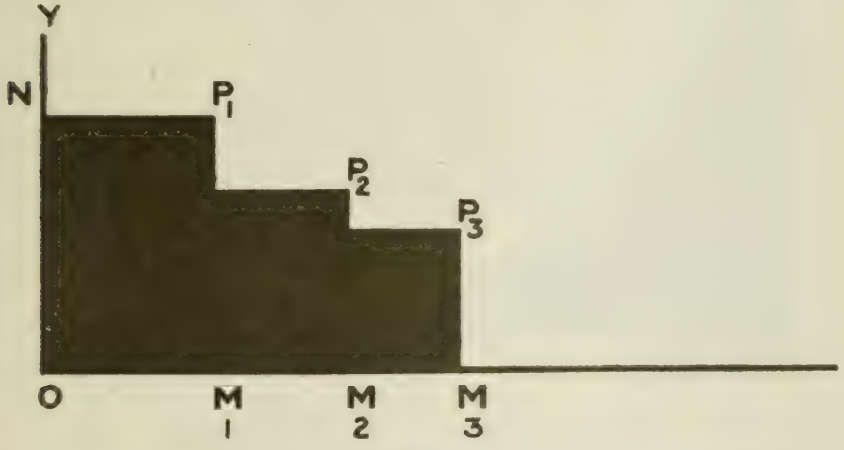


Fig. 1

make only a trifling error, much less than is probably involved in assuming the proper rate. Then let O N (Fig. 1) represent the current production, and O M_1 the value, then completing the rectangle to P_1 the rectangle $OM_1N_1P_1$ would represent the part of

the value of the well due to the production of the current year. Set off beyond M_1 along OX $M_1M_2 = OM_1 \div (1 + i)$, the rate of discount assumed. If this is 2% quarterly $M_1M_2 = 0.9259\ OM_1$.

Erect M_2P_2 so long that its length represents the probable output for next year. M_1M_2 represents the present worth of a barrel of oil to be sold next year. So the rectangle $M_1M_2P_2N_2$ represents the present worth of that year's output. So plotting $M_1M_2M_3$, etc., each the same proportion nearer the preceding than that one was to the one preceding and constructing rectangles on them their total area will represent the present worth of the output of the well.

But the sum of the lines $OM_1M_2M_3$ . . . will not be infinite, even though the life of the mine is infinite, it will approach $13.5 \times OM_1$, that is, in general, $OM_1 \div \{1 - 1/(1 + i)\}$. The total area is about four times that of the first rectangle.

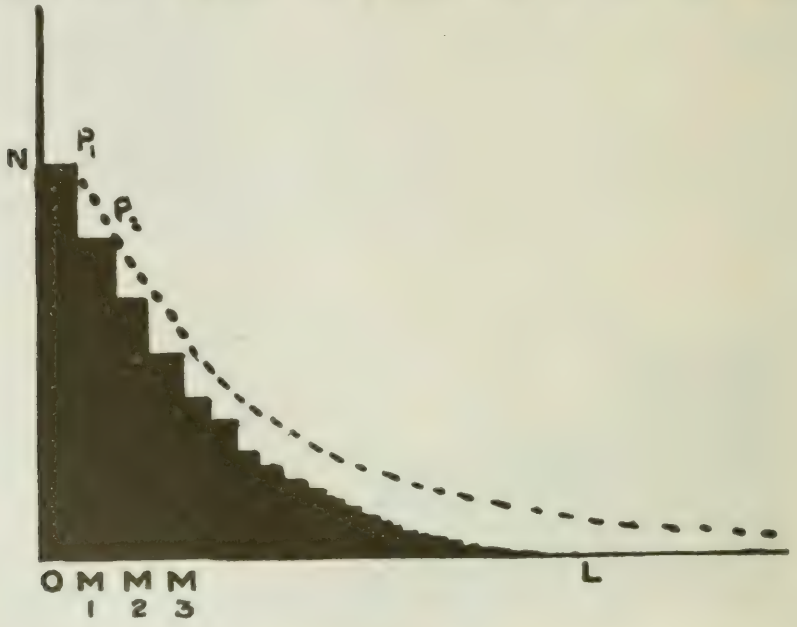


Fig. 2 Value of oil well, production decreasing as indicated by curve; value represented by black area.

That is *the total worth is about four times the value of the first year's production.* The figure (2) shows at a glance of how little importance in computing the value of an oil well is the part of the production after the first few years.

So far we have supposed the price of oil to remain fixed and the annual profit per barrel also. If we do not suppose it to remain fixed we may increase or diminish the successive rectangles in the proportion that we suppose the profit per barrel that year will bear to the current price, but this enters the field of the second problem.

2.—Output uniform, price varying in business cycles.—The computation of the present worth, if we assume the yield to be representable by a curve like P S R T Q (Fig. 3) is mathematical —one solved by electricians and physicists in treating of 'damped vibrations.' Suppose we assume the cycles to repeat

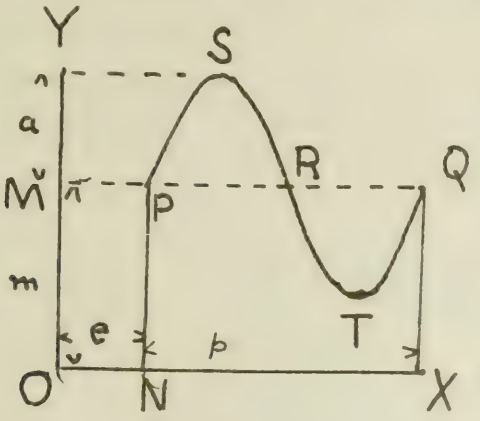


Fig. 3

over and over again; that is, the present worth of the payments to be made during any cycle, will be the same at the beginning of the cycle. Let such payments be $c_1 = c_2 = c_3$, etc. The present value of V is then:

$$V = c_1 + c_2 (1 + i)^{-p} + c_3 (1 + i)^{-p} + c_4 (1 + i)^{2p}.$$

If n is the number of cycles, and p is the number of years in a cycle, therefore—

$$V = \frac{c_1 \{1 - (1 + i)^{-p(n-1-1)}}{1 - (1 + i)^{-p}}, \text{ and this approaches} \frac{c_1}{1 - (1 + i)^{-p}}$$

as the number of cycles becomes infinite.

This leads to the most simple and practical rule for finding the present worth of such an investment.

Estimate the dividends through the next business cycle; find their present worth at the beginning; add; multiply the sum by the reciprocal of 1 less the present worth of $1 payable at the end of the cycle.

Suppose a factory or mine has a fixed output, and other charges which we may for the purpose consider fixed, so that the profits and dividends vary with the price of the product. Suppose this price varies in more or less predictable cycles.

Many such cycles have been outlined from the days of Joseph's vision of the fat and lean kine, to those of Branner and Babson, varying with the weather, with the sun-spots, with the seasons, with cycles of production, and with psychologic factors. Four, seven and eleven years are often cited. Suppose there has been a number of fat years, then the probabilities are that we are more or less near to a streak of lean years, and all experiences show that is the way things go. Obviously the stock is not worth as much, even with the same present yield, as though there was a streak of good years ahead and a streak of poor years just behind. But the amount of difference is often over-estimated. Let us find out how to estimate it:—

For instance, the Lake Superior copper mines show a cycle of nearly 8 years. Multiplying the payments from the Calumet and Hecla for the 8 years previous to 1915 by a factor to reduce them to the worth of their prospect at 7%, or 3½% semi-annually (which is about what money has earned annually invested in Michigan dividend paying copper mines) at the beginning of the eight years we have:—

1915.....	$50 × .5767	28.83
1914.....	10 × .6178	6.18
1913.....	32 × .6618	21.15
1912.....	42 × .7089	29.73
1911.....	24 × .7594	18.25
1910.....	29 × .8135	23.58
1909.....	27 × .8714	23.52
1908.....	20 × .9335	18.67
		169.91

The Calumet and Hecla was then worth in 1907-8 $169.91 for the dividends of the next eight years. If we suppose similar cycles to be repeated indefinitely we must multiply by

$$\frac{1}{1-(1.035)^{-16}} = 2.36,$$

and the stock would have been worth in 1908 $401. That it actually sold that year above $535, may be accounted for partly on the supposition that the famous strike was not foreseen, and partly on the supposition that people are willing to get less than 7% on money invested in Calumet and Hecla. At 5% the calculation would give a value of $560 which is within the range of prices in 1907.

If on the other hand we begin the same cycle of prices with the good years immediately ahead the value will be greater. Suppose, for instance, we have dividends in this order, as might be the case in 1911:

24 × .582 = 14.00	24 × .5767 = 13.82
29 × .662 = 18.10	29 × .6178 = 17.96
27 × .666 = 18.00	27 × .6618 = 17.86
20 × .713 = 14.26	20 × .7089 = 14.17
45 × .763 = 35.40	50 × .7594 = 37.96
10 × .816 = 8.16	10 × .8135 = 8.13
32 × .873 = 27.90	32 × .8714 = 27.95
42 × .934 = 38.20	42 × .9335 = 39.10
174.02	176.95

The dividends for the cycle are worth about $7 more at 7% and the stock as a whole about $17 more; not so very great a difference.

TREATMENT BY CALCULUS

Let us, however, suppose that the yield and value are represented by smooth curves such as P S R T Q (Fig. 3).

The total yield during the time represented by NX is represented by the area under the curve, i.e. P S R T Q X N P . Let y be the annual dividend, a varying value; let PN = OM = m

be the average dividend. Let e be the time from the present to when we next have an average dividend or begin a cycle; let the period of the cycle, the number of years from P to Q, be n. Assume first that the curve is a sine curve and that YM = a can represent the amount of range both above and below the average. The simplest cycle law of all, but from which any cyclical law can be compounded is, $y - m = a \sin 2\pi \frac{(x-e)}{p}$. The present worth of any dividend y at the rate of interest i is, by a well known formula of compound interest, $y\,(1+i)^{-(x-e)}$. Therefore the present worth of all the payments (V) is by the calculus, if represented by a smooth curve,—

$\int_o^\omega y\,(1+i)^{-(x-e)}dx = V$, where ω represents the life of the mine. Therefore,

$$V = \int_o^\omega (a \sin \frac{2\pi}{p}(x-e) + m)\,(1+i)^{-(x-e)}\,dx$$

$$= \int_o^\infty (\sin 2n\,(x-e)/p\,(1+i)^{-(x-e)} + m\int_o^\infty (1+i)^{-(x-e)}\,dx.$$

The second number is of the year's purchase type, and compounds to the present worth of a series of payments of the mean amount (m). The first term will sometimes be subtracted from it, sometimes added to it. Now, as each time x is increased by p, $\frac{2\pi(x-e)}{p}$ is increased by 2π the sine term will have the same value, while the term $(1+i)$ will be multiplied by $(1+i)^p$.

The solution of the summation of the dividends as a continuous area expressed by sine curves is not beyond the resources of the calculus, although somewhat complicated; for the income from o to p we have the formula, letting $1 + i = R$,

$$c_1 = a\int_o^p R^{-x}{}_1, \sin\frac{2\pi}{p}(x-e).\,dx + m\int_o^p R^{-x}dx$$

Two formulae apply—

$$(1)\quad \int e^{kx} \sin nx\, dx = e^{kx} \frac{k \sin nx - n \cos nx}{k^2 + n^2}$$

$$(2)\quad (\int e^{kx}) \int a^x dx = \frac{a^x}{\text{nat log } a}$$

In the a term, multiplying and dividing by R^e we get it into the form (1) by letting $x = (x-e)$, $n = \frac{2\pi}{p}$ and $R^{-1} = e^{+k}$, i.e., $k = \text{nat log } R$ (log R is itself negative). In the m term substitution is obvious.

So we have:—

$$c_1 = \frac{a}{R^e} R^{-(x-e)} \cdot \frac{-\text{nat log } R \sin \frac{2\pi}{p}(x\text{-}e) - \frac{2\pi}{p} \cos \frac{2\pi}{p}(x\text{-}e)}{(-\text{nat log } R)^2 + \left(\frac{2\pi}{p}\right)^2} \Bigg|_0^p$$

$$+ \frac{m}{\text{nat log } R}(R^{-p}-1)$$

The numerator of the first term, of which a is a factor, is:—

$$a\, R^{-p}\left(\text{nat log } R \sin 2\pi \frac{e}{p} - \frac{2\pi}{p} \cos 2\pi \frac{e}{p}\right)$$

$$- a \left(\text{nat log } R \sin 2\pi \frac{e}{p} - \frac{2\pi}{p} \cos 2\pi \frac{e}{p}\right.$$

Therefore;—

$$c_1 = \frac{a\,(R^{-p}-1)}{(\text{nat log } R^{-p})^2 + \left(\frac{2\pi}{p}\right)^2} \left\{ \frac{}{\text{nat log } R} \cdot \sin 2\pi \frac{e}{p} - \frac{2\pi}{p} \cos 2\pi \frac{e}{p} \right\}$$

$$+ \frac{m\,(R^{-p}-1)}{\text{nat log } R}$$

We note that the second term does not vary no matter where we begin, so that the range of value up and down according to the good years and bad years is dependent only on the first term.

The amount of this variation in value of the stock can be estimated if we have the length of the period, the rate of interest and discount, and the range of annual yield. For short cycles, however, the method of assuming a probable series of dividends is much more rapid and it is always as accurate.

Suppose we take a four year cycle and 5% interest; to get the total present worth we should multiply the present worth of four years' dividend by 5.65, about 6.

Suppose the average dividend is $9 and the four year cycle of dividends is $9, $9 + 7, $9, $9—7. (I take $9 and $7 at random, and any other numbers may be substituted.) The value (c) of the cycle of dividends will be according as $9 is followed by $9 + $7 or $9 + $7 is followed by $9 or $9 is followed by $9—$7 or $9—$7 comes first respectively, the present worth of a uniform dividend of $9, i.e. $9 i.e. $9 $(1 + R + R^2 + R^3—)$ plus or minus a varying quantity to wit + 7R $(1—R^2)$, or + 7 $(1—R^1)$, or — 7R $(1—R^2)$, or — 7 $(1—R^2)$ respectively; if R = .95238, i.e. the rate of interest is 5% the figures will be + 7 (.084), 7 (.09), — 7 (.084), — (.09) respectively. The present worth of the cycle of dividends c will then range up and down, according to the variation in the order of dividends nearly one-tenth of the range in the dividends themselves (.09). The present worth of the investment will be about six times as much so that it will range about 54% of the range in dividends.

If we should take larger cycles of good and bad years, while the range of value in the cycle would be greater, yet the factor required to pass from the value of a cycle of dividends to the present worth of an indefinite number of cycles would be less and the result would not be so very different. The larger the cycle and the greater the discount rate R, the greater will be the variation in value according to whether a big or small

dividend were in prospect, for if there were supposed to be no discount then it would make no difference whether the big dividends came first or the little.

We see then that the permanent investment value of a stock with fluctuating yield increases as times are good i.e., according as big dividends are soon to be paid, by an amount only about half the increase of the extra dividends over the average dividend to be expected. The loss in value is only about half the cut in dividend also.

This result is less than I think is popularly expected. A stock will often go down more than the value of a dividend cut.

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